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NOVEMBER 1964

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis and interpretation of data on environmental radiation levels. The Department delegated this responsibility to the Division of Radiological Health, Public Health Service.

Radiological Health Data is published by the Public Health Service on a monthly basis. Data are provided to the Division of Radiological Health by other Federal agencies, State health departments, and foreign governments. Pertinent original data and interpretive papers are invited from investigators. Accepted material will be appropriately credited. The reports are reviewed by a Board of Editorial Advisors with representatives from the following Federal agencies:

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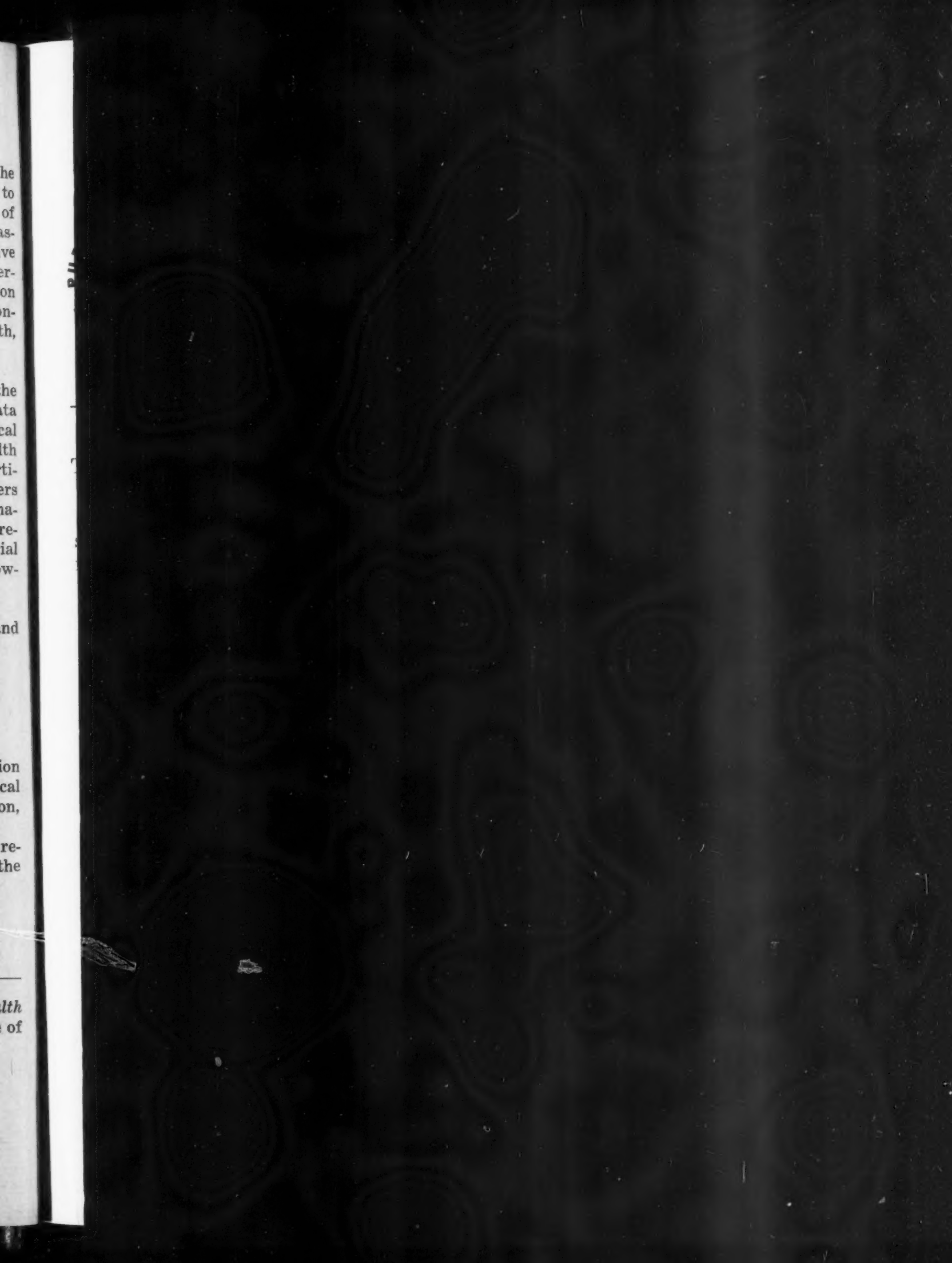

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • Division of Radiological Health

Section I—Air and Fallout

FISSION PRODUCT BETA ACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of gross beta activity in air and precipitation provides one of the earliest and most sensitive indications of changes in environmental fission product activity. Although this surveillance does not provide enough information to assess human radiation exposure from fallout, it is widely used as the basis for alerting systems for determining when to intensify monitoring in other phases of the environment.

Surveillance data from a number of national programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. Data provided by programs of the Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization are presented individually in tabular form and are also compared in beta concentration isograms.

1. Radiation Surveillance Network July 1964

Division of Radiological Health, Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) of the PHS Division of Radiological Health which gathers samples from 70 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The alerting function of the network is provided by field estimates of the gross beta activity of airborne particulates on the filters. These determinations are performed about 5 hours after the end of the sampling period to allow for decay of naturally-occurring radon daughters. The network station operators regularly submit their field estimates to the Radiation Surveillance Center, Division of Radiological Health, Washington, D. C. These field estimates are reported elsewhere on a monthly basis (*1*). When unusually high air levels are reported, appropriate Federal and State officials are promptly notified.

Air

Airborne particulates are collected continuously on carbon-loaded cellulose dust filters 4 inches in diameter. A volume of about 1800 cubic meters of air is drawn through each filter during the 24-hour sampling period by a high volume centrifugal blower.

The filters are forwarded to the Radiation Surveillance Network laboratory in Rockville, Maryland, where the gross beta activity is measured using a thin-window, gas-flow proportional counter, calibrated with a Sr^{90}–Y^{90} standard. Each filter is counted at least 3 days

FIGURE 1.—RADIATION SURVEILLANCE NETWORK SAMPLING STATIONS

after the end of the sampling period and again 7 days later. The initial 3-day aging of the sample eliminates interference from naturally-occurring radon and thoron daughters. By using the two counts and the Way-Wigner formula (*2*), the age of fission products is estimated, and the activity extrapolated to the time of collection.[1] The daily concentrations and estimated ages of selected samples are reported by the PHS in a monthly RSN report (*1*).

The twenty highest daily air measurements in July (table 1) ranged from 2.93 to 4.54 pc/m^3. In June the twenty highest samples ranged from 4.85 to 6.62 pc/m^3. Time profiles of gross beta activity in air for eight RSN stations are shown in figure 2. The July 1964 average gross beta concentration in air for each station is given in table 2. The network average for July (0.86 pc/m^3) decreased from the June average (1.58 pc/m^3).

[1] If a sample contains a mixture of fresh and old fission products, the age estimated by the Way-Wigner formula is some intermediate value and cannot be used for estimating date of formation.

Precipitation

Continuous sampling for total precipitation is conducted at most stations on a daily basis, using funnels with collection areas of 0.4 square meter. A 500-ml aliquot of the collected precipitation is evaporated to dryness, and the residue is forwarded to the laboratory for

TABLE 1.—GROSS BETA ACTIVITY OF THE TWENTY INDIVIDUAL RSN AIR FILTERS HAVING HIGHEST ACTIVITIES DURING JULY 1964

Station		Date July	Concentration (pc/m^3)
Colo:	Denver	13	3.05
D.C:	Washington	2	3.08
Maine:	Augusta	1	2.93
Mich:	Lansing	5	3.01
		6	3.17
Nev:	Las Vegas	7	3.09
Ohio:	Painesville	1	3.09
		6	3.18
Pa:	Harrisburg	1	3.90
		2	3.81
		3	4.54
		6	3.94
		8	3.86
		11	3.00
		12	3.93
		15	3.16
		17	3.69
		18	4.49
Vt:	Barre	3	3.17
Utah:	Salt Lake City	7	3.63

TABLE 2.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, JULY 1964

Station location		Air surveillance					Precipitation measurements	
		Number of samples	Gross beta activity (pc/m³)			Last profile in *RHD*	Average concentration (pc/liter)	Total deposition (nc/m²)
			Maximum	Minimum	Average [a]			
Ala:	Montgomery	22	1.67	0.14	0.64	Aug 64	250	36.6
Alaska:	Adak	23	0.63	<0.10	0.19	Nov 64	[b]—	—
	Anchorage	31	1.05	<0.10	0.26	Jul 64	380	10.7
	Attu	31	1.33	<0.10	0.27	Dec 63	—	—
	Fairbanks	28	1.84	<0.10	0.64	Aug 64	380	11.9
	Juneau	7	0.39	<0.10	0.23	Sep 64	200	4.2
	Kodiak	17	0.92	<0.10	0.21	Oct 64	—	—
	Nome [c]							
	Point Barrow [a]							
	St. Paul Island	29	1.89	<0.10	0.40	Mar 64	—	—
Ariz:	Phoenix	28	1.73	0.28	0.55	Sep 64	—	—
Ark:	Little Rock	29	1.41	0.37	0.87	Sep 64	240	12.5
Calif:	Berkeley	23	0.74	<0.10	0.35	Oct 64	—	—
	Los Angeles	23	1.31	0.28	0.58	Feb 64	—	—
Canal Zone:	Ancon	11	0.21	<0.10	0.11	Nov 64	—	—
Colo:	Denver	28	3.05	0.37	0.85	Oct 64	200	4.0
Conn:	Hartford	31	2.07	0.18	0.82	Oct 64	270	19.7
Del:	Dover	21	2.50	0.20	0.90	Aug 64	—	—
D. C:	Washington	30	3.08	0.17	1.22	Aug 64	450	22.5
Fla:	Jacksonville	30	1.85	0.18	0.79	Sep 64	210	48.4
	Miami	30	1.38	0.32	0.79	Oct 64	240	43.4
Ga:	Atlanta	2	1.67	1.17	1.42	Jul 64	230	29.2
Guam:	Agana	29	0.43	<0.10	0.19	Apr 64	—	—
Hawaii:	Honolulu	31	1.22	<0.10	0.47	Feb 64	300	15.0
Idaho:	Boise	25	2.86	0.55	1.58	Dec 63	—	—
Ill:	Springfield	24	1.86	0.54	1.11	Mar 64	—	—
Ind:	Indianapolis	30	2.44	0.66	1.22	Jul 64	440	57.9
Iowa:	Iowa City	30	1.98	0.38	0.99	Nov 64	340	3.9
Kans:	Topeka	22	1.07	0.30	0.67	Jul 64	200	2.9
Ky:	Frankfort	30	2.15	0.62	1.20	Feb 64	400	16.9
La:	New Orleans	31	1.44	<0.10	0.51	Mar 64	200	26.4
Maine:	Augusta	31	2.93	0.30	0.97	Mar 64	380	52.3
	Presque Isle	28	2.90	0.26	0.96	Nov 64	450	31.9
Md:	Baltimore	22	2.13	0.12	0.94	Oct 64	420	17.8
	Rockville	20	1.56	0.25	0.82	Mar 64	—	—
Mass:	Lawrence	30	2.36	0.13	0.95	Aug 64	530	35.1
	Winchester	27	1.59	0.14	0.78	Apr 64	760	44.7
Mich:	Lansing	31	3.17	0.59	1.70	Feb 64	420	25.9
Minn:	Minneapolis	30	1.41	0.37	0.74	Mar 64	460	25.5
Miss:	Jackson	31	1.88	0.34	0.87	Apr 64	210	28.0
	Pascagoula [c]							
Mo:	Jefferson City	31	1.25	0.40	0.72	Jul 64	210	21.5
Mont:	Helena	30	2.15	0.23	1.21	Nov 64	1,000	24.0
Nebr:	Lincoln [c]							
Nev:	Las Vegas	26	3.09	0.24	0.87	Aug 64	—	—
N. H:	Concord	21	2.31	0.17	1.06	Feb 64	—	—
N. J:	Trenton	30	1.78	0.16	0.88	Apr 64	210	9.1
N. Mex:	Santa Fe	28	1.30	0.13	0.43	Nov 64	220	2.7
N. Y:	Albany	21	1.97	0.43	0.98	Jul 64		
	Buffalo	9	2.20	0.88	1.57	Nov 64	—	—
	New York	29	2.07	0.72	0.91	Dec 63	—	—
N. C:	Gastonia	31	2.31	0.17	0.84	Nov 64	200	43.4
N. Dak:	Bismarck	28	2.63	0.77	1.34	Feb 64	380	33.3
Ohio:	Cincinnati	21	1.72	0.75	1.12	Aug 64	—	—
	Columbus	31	2.90	0.81	1.59	Apr 64	730	54.9
	Painesville	29	2.18	0.89	1.74	Oct 64	410	35.7
Okla:	Oklahoma City	30	1.48	0.24	0.66	Apr 64	—	—
	Ponca City	31	0.96	0.10	0.43	Oct 64	330	6.2
Ore:	Portland	31	1.72	0.28	0.89	Oct 63	290	5.4
Pa:	Harrisburg	31	4.54	0.38	2.15	Jul 64	200	4.5
P. R:	San Juan	27	1.16	<0.10	0.65	Mar 64	230	7.5
R. I:	Providence	24	2.69	0.11	1.03	Jan 64	290	22.5
S. C:	Columbia	27	2.05	0.11	0.70	Dec 63	220	60.3
S. Dak:	Pierre	31	2.17	0.43	0.96	Sep 64	290	1.76
Tenn:	Nashville	31	2.69	0.32	1.06	Jan 64	450	37.5
Tex:	Austin	30	1.29	0.15	0.52	Aug 64	410	5.2
	El Paso	31	1.97	0.17	0.58	Jan 64	600	2.0
Utah:	Salt Lake City	31	3.63	0.26	1.10	Aug 63	760	0.9
Vt:	Barre	29	3.17	0.30	1.41	Sep 64	450	2.0
Va:	Richmond	31	2.10	<0.10	0.74	Sep 64	210	34.8
Wash:	Seattle	31	0.63	<0.10	0.28	Jul 64	480	9.1
W. Va:	Charleston	30	2.65	0.15	1.13	Dec 63	580	37.8
Wis:	Madison	30	2.00	0.48	1.32	Sep 54	290	26.6
Wyo:	Cheyenne	31	2.37	0.35	0.81	Aug 64	1,600	42.8
Network summary		1,878	4.54	<0.10	0.86		325	23.9

[a] The monthly average is calculated by weighting the individual samples with sampling period length. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed before the average.

[b] Dash indicates no precipitation sample collected.

[c] Blank indicates no report received.

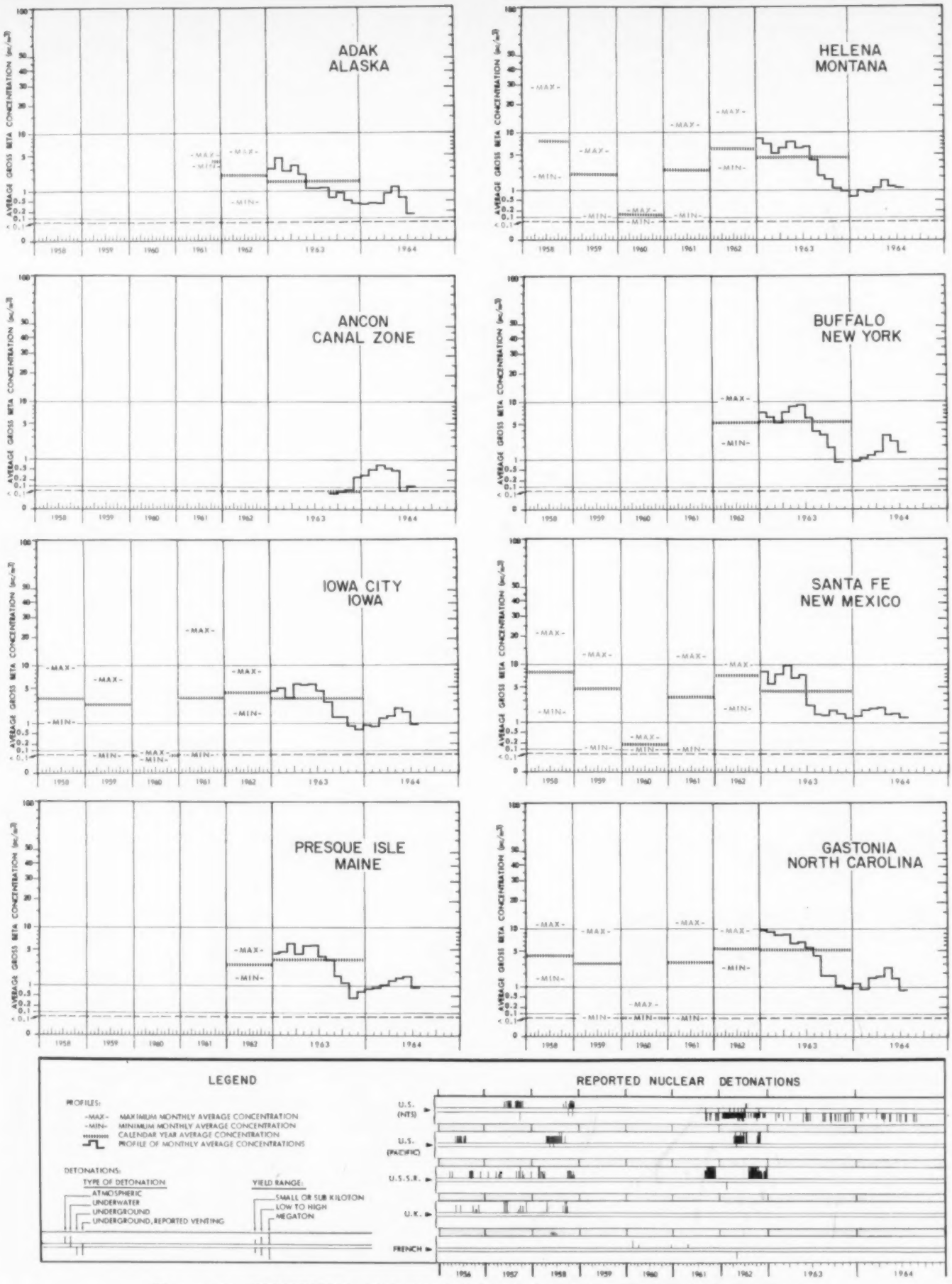

FIGURE 2.—MONTHLY AND YEARLY PROFILES OF BETA ACTIVITY IN AIR—RADIATION SURVEILLANCE NETWORK, 1958–JULY 1964

analysis. If the collected sample is between 200 and 500 ml, the entire sample is evaporated. When a sample is smaller than 200 ml (equivalent to 0.5 mm or 0.02 inches of rainfall), the volume of precipitation is reported, but no analysis is made.

In the laboratory the gross beta activity in precipitation is determined by counting the evaporated sample by the same method used for analyzing the air filters, including the extrapolation to time of collection. Deposition for the sample is determined by:

$$D = \frac{CP}{1000}$$

where D is the deposition in nc/m^2, C is the concentration in pc/liter, and P is the depth of precipitation in mm. The individual values of deposition and depth of precipitation are totaled for the month, and the average concentration for the month, $\overline{C}$, is determined by:

$$\overline{C} = \frac{\Sigma D}{\Sigma P} \times 1000$$

The July 1964 average concentrations and total depositions are given in table 2.

2. Canadian Air Monitoring Program [2] July 1964

Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (see figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of the National Health and Welfare (*3–7*).

Air

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch-diameter filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa. At the laboratory, a 2-inch-diameter disk is cut from each filter and counted with a thin-end-window, gas-flow, Geiger-Mueller counter system, calibrated with a Sr^{90}–Y^{90} standard. Four successive measurements are made on each filter to permit correction for natural activities and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for July 1964 are given in table 3 and presented in conjunction with U. S. and Mexican data by an isogram map (figure 5).

Precipitation

The amount of radioactive fallout deposited on the ground is determined from measurements on material collected in special polyethylene-lined rainfall pots. The collection period for each sample is one month. After transfer of the water to the sample container, the polyethylene liner is removed, packed with the sample, and sent to the laboratory.

Strontium and cesium carriers are added to all samples on arrival at the laboratory. Other carriers are also added to selected samples according to the specific radionuclides to be determined. The samples are then filtered and the filtrate evaporated to near dryness. The filter paper containing insoluble matter is ignited together with the polyethylene liner at 450° C. The ash is combined with the soluble fraction, transferred to a glass planchet, evaporated under an infra-red lamp and then counted with a thin-end-window Geiger-Mueller counter calibrated with a Sr^{90}–Y^{90} source. Gross beta activities for July 1964 samples are given in table 3. Radionuclide analyses are reported quarterly in *RHD*.

[2] Data from *Radiation Protection Programs, Vol. 2, No. 8:* 11-24, Radiation Protection Division, Canadian Department of National Health and Welfare, Ottawa, Canada.

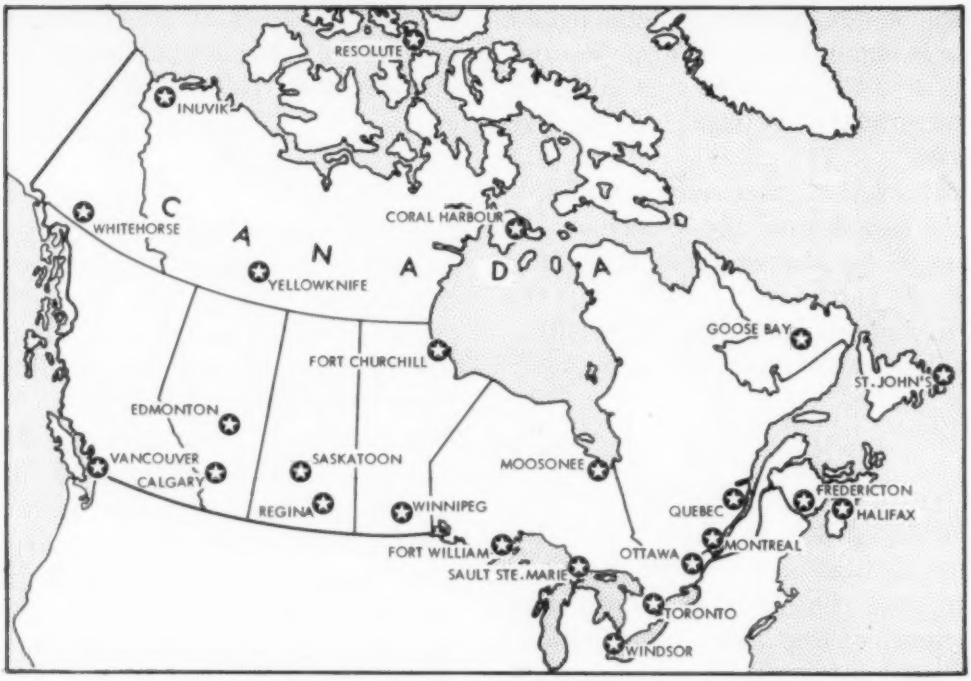

FIGURE 3.—CANADIAN AIR AND PRECIPITATION SAMPLING STATIONS

TABLE 3.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, CANADA, JULY 1964

Station	Air surveillance				Precipitation data	
	Number of samples	Gross beta activity (pc/m³)			Average concentration (pc/liter)	Total deposition (nc/m²)
		Maximum	Minimum	Average		
Calgary	31	2.4	0.8	1.4	480	34.6
Coral Harbour	30	2.3	0.1	0.9	1,201	13.7
Edmonton	31	1.8	0.3	1.0	525	39.4
Ft. Churchill	31	1.9	0.1	0.9	894	40.8
Ft. William	29	1.7	0.4	1.0	1,067	19.8
Fredericton	31	2.2	0.1	0.8	466	26.5
Goose Bay	31	1.6	0.1	0.8	470	60.1
Halifax	28	2.2	0.1	0.5	334	48.3
Inuvik	31	2.5	0.1	1.0	752	46.6
Montreal	30	2.6	0.2	1.2	431	49.9
Moosonee	30	2.1	0.1	1.0	472	20.6
Ottawa	29	2.3	0.5	1.1	647	59.3
Quebec	29	2.2	0.1	1.0	518	41.1
Regina	31	2.8	0.8	1.4	886	81.8
Resolute	30	1.3	0.1	0.3	102	26.4
St. John's, Nfld.	29	2.1	0.1	0.7	253	25.7
Saskatoon	30	2.5	0.4	1.3	1,188	26.5
Sault Ste. Marie	28	2.3	0.3	1.1	277	29.0
Toronto	31	1.8	0.4	1.1	431	49.0
Vancouver	31	0.9	0.1	0.4	604	48.1
Whitehorse	30	1.5	0.1	0.5	488	17.6
Windsor	30	2.5	0.5	1.2	699	38.5
Winnipeg	31	1.9	0.5	1.2	1,346	30.7
Yellowknife	31	2.2	0.3	1.2	1,647	6.7
Network summary		2.1	0.1	1.0	674	36.7

3. Mexican Air Monitoring Program July 1964

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the *Comisión Nacional de Energía Nuclear* (CNEN), Mexico City. From 1952 to 1961 the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN (*8–12*).

In 1961 the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance network. This network consists of 17 stations (see figure 4), twelve of which are located at airports and operated by airline personnel. The remaining five stations are located at Mexico City, Mérida, Veracruz, San Luis Potosí and Ensenada. Staff members of the DRP operate the station at Mexico City while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Dersérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air for 24 hours a day, 3 or 4 days a week at the rate of approximately 1,200 cubic meters per day, through a high-efficiency, 6 x 8-inch glass fiber filter, using high volume samplers. After each 24 hour sampling period, the filter is removed and forwarded via air mail to the "Laboratorio de Estudios sobre Contaminación Radiactiva", CNEN, in Mexico City for assay of gross beta activity. A minimum of 3 or 4 days after collection is allowed for decay of radon and thoron daughter natural radioactivity. Data are not extrapolated to time of collection.

FIGURE 4.—FALLOUT NETWORK SAMPLING STATIONS IN MEXICO

Results

The maximum, minimum and average fission product beta concentrations in surface air during July 1964 are presented in table 4. The data are also represented in the beta activity isogram map of North America, figure 5.

TABLE 4.—GROSS BETA ACTIVITY OF AIRBORNE PARTICULATES, MEXICO, JULY 1964

[Concentrations in pc/m³]

Station	Number of Samples	Maximum	Minimum	Average
Acapulco	11	0.3	0.1	0.2
Ciudad Juárez	25	1.0	0.1	0.4
Chihuahua	15	1.5	0.1	0.6
Ensenada	11	1.0	0.2	0.6
Guadalajara	12	0.4	0.1	0.3
Guaymas	19	0.9	0.3	0.5
La Paz	18	1.0	0.1	0.5
Matamoros	23	1.2	0.1	0.4
Mazatlán	6	0.7	0.1	0.2
Mérida	9	1.0	0.1	0.3
México, D.F.	14	0.9	0.1	0.3
Nuevo Laredo	13	1.5	0.2	0.6
San Luis Potosí	11	0.4	0.1	0.2
Tampico	31	2.0	0.1	0.4
Torreón	24	0.9	0.1	0.5
Tuxtla Gutiérrez *				
Veracruz	21	1.3	0.1	0.4

* Temporarily shut down.

Investigations; in Lima, Peru, by the Institute of Occupational Health; and in Santiago, Chile, by the Occupational Health Service. The Kingston station began operation in March 1964, and the other three were started near the end of 1962.

The July 1964 air monitoring results from the four participating countries are given in table 5. The Caracas and Jamaica stations, included in figure 5 with the July averages adjusted by the RSN intercalibration factor,[3] were used in positioning the beta concentration isograms.

TABLE 5.—GROSS BETA ACTIVITY IN AIR, JULY 1964

[Concentrations in pc/m³]

Sampling stations	No. of samples	Maximum	Minimum	Average *
Kingston, Jamaica	18	0.92	0.22	0.51
Caracas, Venezuela	22	0.82	<0.10	0.23
Lima, Peru	22	0.17	<0.10	0.10
Santiago, Chile	13	0.73	<0.10	0.18

* The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed in front of the average.

[3] The RSN factor is 1.28.

4. Pan American Air Sampling Program July 1964

Pan American Health Organization and Public Health Service

Gross beta activity in air is monitored by four countries in the Americas under the auspices of a collaborative program developed by the Pan American Health Organization and the Public Health Service (PHS) for assisting countries of the Americas in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network.

The four air sampling stations included in the program are operated by the technical staff of the Ministry of Health in each country. The station in Kingston, Jamaica, is operated by the Public General Hospital; in Caracas, Venezuela, by the Venezuelan Institute for Scientific

5. Gross Beta Activity In Air, North America July 1964

Beginning with January 1963 data, monthly average concentrations of airborne gross beta activity in Canada and the United States have been presented in combined form as isogram maps of most of North America. The data from the Radiation Surveillance Network and the Canadian Air Network were adjusted to each other by means of an intercalibration factor derived by Lockhart and Patterson (*13*).

With the formation of the Mexican Air monitoring program, new intercalibration ratios were determined, this time including the Canadian Network, Radiation Surveillance Network, National Air Sampling Network, the HASL 80th Meridian Network, and the Mexican Network (*14*). The new intercalibration factors reflect some changes in standardization in both the RSN and the Canadian Air Network, effective September 1963.

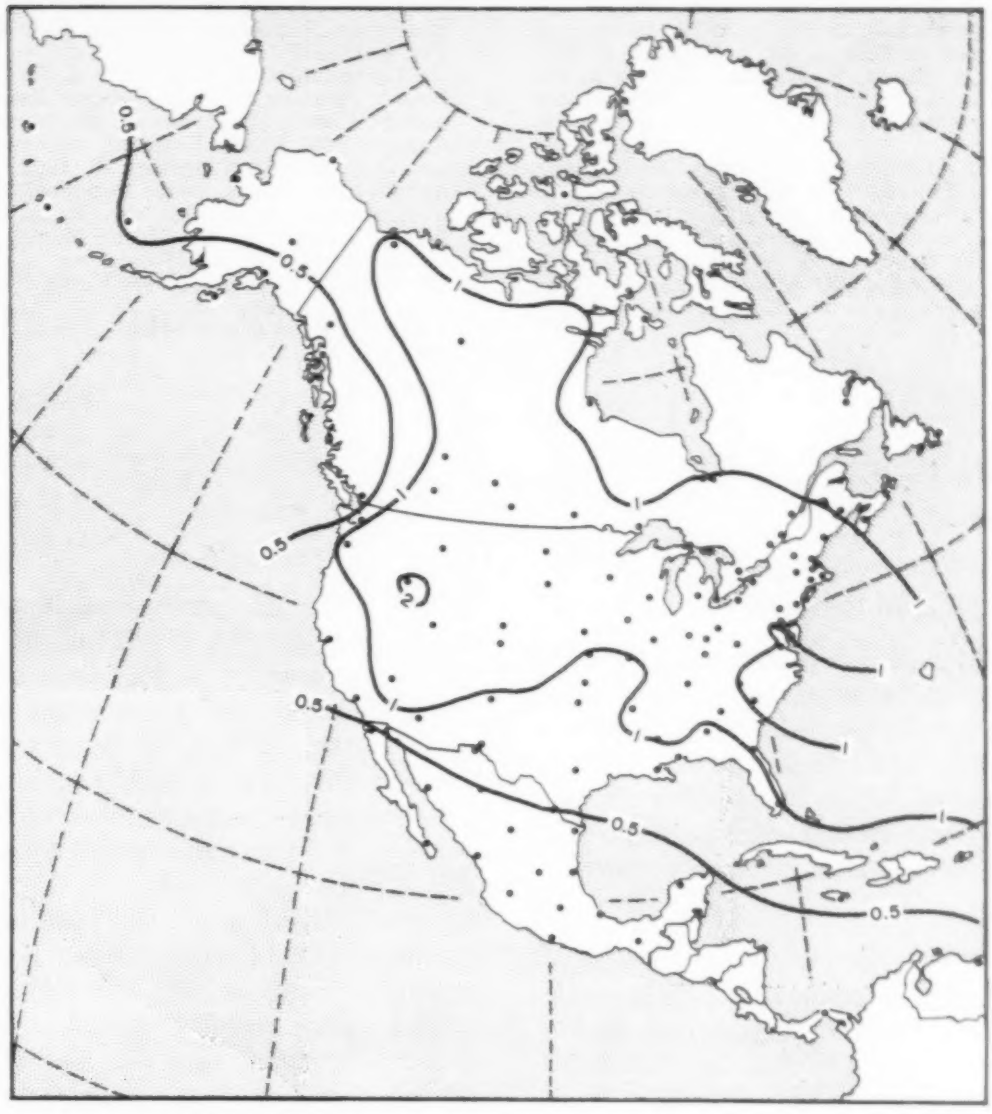

FIGURE 5.—ISOGRAM OF AVERAGE GROSS BETA CONCENTRATIONS IN AIR, NORTH AMERICA, JULY 1964

Figure 5 shows the July 1964 activity in air throughout North America based on the data from the Canadian Air Monitoring Program, the Radiation Surveillance Network and Mexican Air Monitoring program. An intercalibration factor of 1.28 was applied to the RSN data and the Mexican data were multiplied by 0.81 in order to adjust them to Canadian data.

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Results

The maximum, minimum and average fission product beta concentrations in surface air during July 1964 are presented in table 4. The data are also represented in the beta activity isogram map of North America, figure 5.

TABLE 4.—GROSS BETA ACTIVITY OF AIRBORNE PARTICULATES, MEXICO, JULY 1964

[Concentrations in pc/m³]

Station	Number of Samples	Maximum	Minimum	Average
Acapulco	11	0.3	0.1	0.2
Ciudad Juárez	25	1.0	0.1	0.4
Chihuahua	15	1.5	0.1	0.6
Ensenada	11	1.0	0.2	0.6
Guadalajara	12	0.4	0.1	0.3
Guaymas	19	0.9	0.3	0.5
La Paz	18	1.0	0.1	0.5
Matamoros	23	1.2	0.1	0.4
Mazatlán	6	0.7	0.1	0.2
Mérida	9	1.0	0.1	0.3
México, D.F.	14	0.9	0.1	0.3
Nuevo Laredo	13	1.5	0.2	0.6
San Luis Potosí	11	0.4	0.1	0.2
Tampico	31	2.0	0.1	0.4
Torreón	24	0.9	0.1	0.5
Tuxtla Gutiérrez [a]				
Veracruz	21	1.3	0.1	0.4

[a] Temporarily shut down.

Investigations; in Lima, Peru, by the Institute of Occupational Health; and in Santiago, Chile, by the Occupational Health Service. The Kingston station began operation in March 1964, and the other three were started near the end of 1962.

The July 1964 air monitoring results from the four participating countries are given in table 5. The Caracas and Jamaica stations, included in figure 5 with the July averages adjusted by the RSN intercalibration factor,[3] were used in positioning the beta concentration isograms.

TABLE 5.—GROSS BETA ACTIVITY IN AIR, JULY 1964

[Concentrations in pc/m³]

Sampling stations	No. of samples	Maximum	Minimum	Average [a]
Kingston, Jamaica	18	0.92	0.22	0.51
Caracas, Venezuela	22	0.82	<0.10	0.23
Lima, Peru	22	0.17	<0.10	0.10
Santiago, Chile	13	0.73	<0.10	0.18

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed in front of the average.

[3] The RSN factor is 1.28.

4. Pan American Air Sampling Program July 1964

Pan American Health Organization and Public Health Service

Gross beta activity in air is monitored by four countries in the Americas under the auspices of a collaborative program developed by the Pan American Health Organization and the Public Health Service (PHS) for assisting countries of the Americas in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network.

The four air sampling stations included in the program are operated by the technical staff of the Ministry of Health in each country. The station in Kingston, Jamaica, is operated by the Public General Hospital; in Caracas, Venezuela, by the Venezuelan Institute for Scientific

5. Gross Beta Activity In Air, North America July 1964

Beginning with January 1963 data, monthly average concentrations of airborne gross beta activity in Canada and the United States have been presented in combined form as isogram maps of most of North America. The data from the Radiation Surveillance Network and the Canadian Air Network were adjusted to each other by means of an intercalibration factor derived by Lockhart and Patterson (*13*).

With the formation of the Mexican Air monitoring program, new intercalibration ratios were determined, this time including the Canadian Network, Radiation Surveillance Network, National Air Sampling Network, the HASL 80th Meridian Network, and the Mexican Network (*14*). The new intercalibration factors reflect some changes in standardization in both the RSN and the Canadian Air Network, effective September 1963.

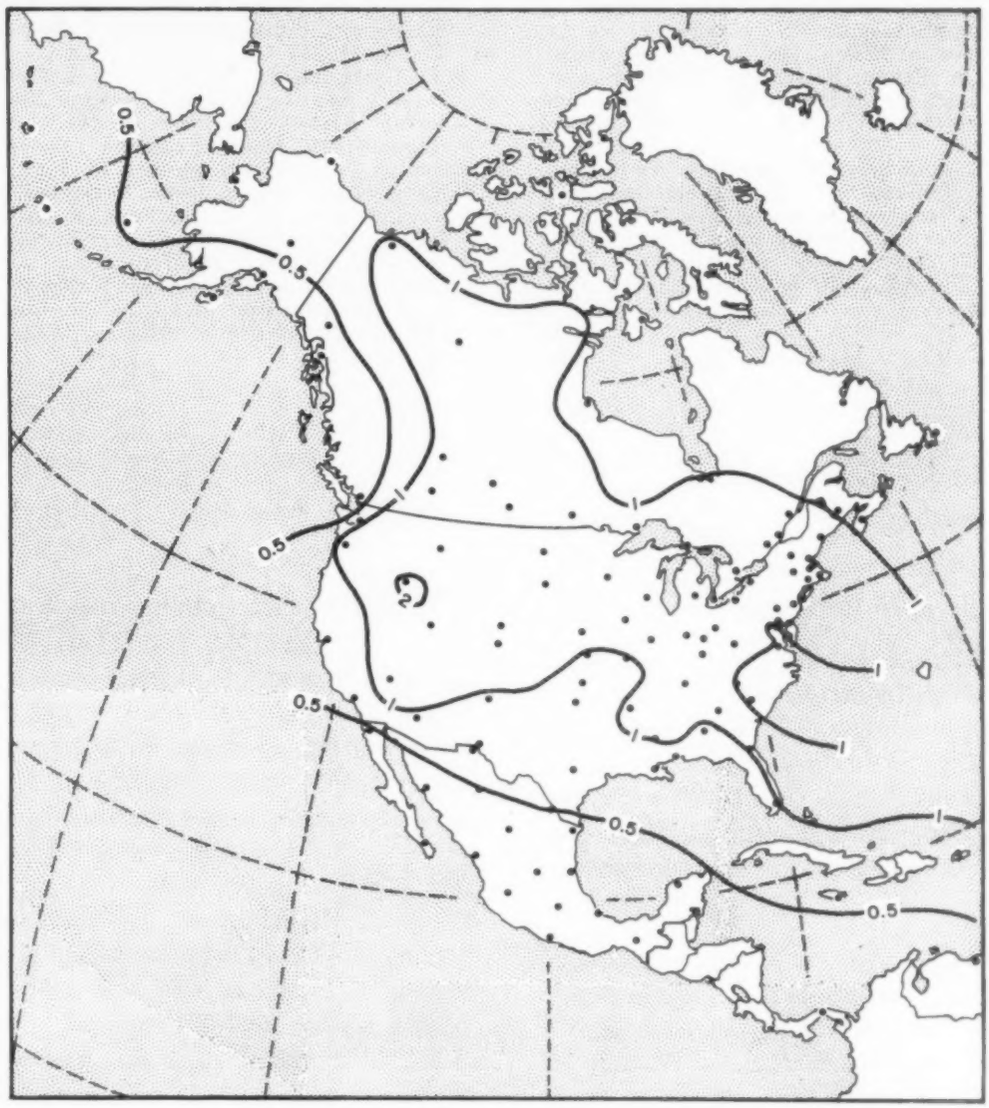

FIGURE 5.—ISOGRAM OF AVERAGE GROSS BETA CONCENTRATIONS IN AIR, NORTH AMERICA, JULY 1964

Figure 5 shows the July 1964 activity in air throughout North America based on the data from the Canadian Air Monitoring Program, the Radiation Surveillance Network and Mexican Air Monitoring program. An intercalibration factor of 1.28 was applied to the RSN data and the Mexican data were multiplied by 0.81 in order to adjust them to Canadian data.

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EVALUATION OF RADIATION SURVEILLANCE NETWORK EXTERNAL GAMMA RADIATION DATA, 1959–1963

Warren W. Church[1]

The Radiation Surveillance Network (RSN) was established in 1956 to provide information on gross beta activities in surface air and in precipitation throughout the United States. Daily measurements of external gamma activity were made in addition to the collection of air and precipitation samples at each of the network's seventy-four stations.

The methodology used by the RSN for measuring external gamma activity (*1*) is briefly described as follows: The probe of a Geiger-Mueller survey meter (Thyac model 389 or model 489) is held three feet above the roof or ground for 60 seconds. During this period the operator estimates the average meter reading. (Prior to any measurements, the probe is held up to a small check source to insure that the meter is operating properly).

The Public Health Service reported monthly averages of external gamma activities at each station in the *Tabulation of Findings, Public Health Service, Radiation Surveillance Network,* (*2*) for the period May 1956 through September 1962, and in *Radiological Health Data* (*3*) for the period January 1960 through September 1962.

Significance of External Gamma Measurements

After the reporting of external gamma measurements was discontinued in September 1962, a study was made to determine whether departures noted in individual stations during the period, 1959–1963, could be associated with other fallout data and whether the routine reporting of monthly averages was warranted.

Table 1 was developed to show the maximum, minimum and median monthly average external gamma measurements for each station from November 1959 through September 1962. With respect to the variability of these averages, nine of the stations consistently reported only one value. Only one or two readings deviated from the median at several other stations.

As a further evaluation of external gamma data, two statistical techniques were employed. First, a control chart was prepared to determine possible trends in external gamma averages (figure 1). Secondly, a correlation study was made to determine if changes in individual external gamma measurements could be related to fallout activity deposited by precipitation.

In the first study, composite monthly external gamma averages were plotted against time. (The geographically representative stations selected for this chart are indicated by

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FIGURE 1.—CONTROL CHART—MONTHLY EXTERNAL GAMMA AVERAGES FROM 21 REPRESENTATIVE RSN STATIONS

footnote reference a in table 1). A line representing the mean of the composite averages and two dashed lines indicating the three-sigma deviations from this mean are used as control lines on the graph. Since all points on the graph are grouped around the mean and are well within the three-sigma control lines, it can be concluded that the composite data did not indicate any significant changes or trends in the external gamma averages during the period from November 1959 through July 1963.

TABLE 1.—MINIMUM, MAXIMUM AND MEDIAN MONTHLY AVERAGE RSN EXTERNAL GAMMA MEASUREMENTS FOR EACH STATION REPORTED BY THE PHS, NOVEMBER 1959 THROUGH SEPTEMBER 1962

Station location	Minimum (mr/hr)	Maximum (mr/hr)	Median (mr/hr)
Anchorage, Alaska	0.01	0.01	0.01
Fairbanks, Alaska	0.01	0.01	0.01
Juneau, Alaska [a]	0.01	0.02	0.01
Phoenix, Ariz	0.01	[b] 0.09	0.01
Little Rock, Ark. [a]	0.01	0.02	0.02
Berkeley, Calif. [a]	0.01	0.02	0.01
Los Angeles, Calif	0.01	0.02	0.01
Denver, Colo	0.02	0.02	0.02
Hartford, Conn	0.01	0.02	0.01
District of Columbia [a]	0.02	0.04	0.02
Jacksonville, Fla. [a]	0.01	0.03	0.01
Atlanta, Ga. [a]	0.02	0.03	0.02
Honolulu, Hawaii [a]	0.01	0.05	0.02
Boise, Idaho	0.01	0.02	0.02
Springfield, Ill	0.01	0.03	0.01
Indianapolis, Ind. [a]	0.01	0.02	0.01
Iowa City, Iowa [a]	0.01	0.03	0.01
Topeka, Kans. [a]	0.02	0.03	0.02
New Orleans, La. [a]	0.01	0.02	0.01
Baltimore, Md	0.01	0.02	0.02
Lawrence, Mass. [a]	0.01	0.02	0.02
Lansing, Mich	0.02	0.02	0.02
Minneapolis, Minn. [a]	0.01	0.02	0.01
Jefferson City, Mo	0.01	0.01	0.01
Helena, Mont. [a]	0.01	[b] 0.07	0.03
Trenton, N. J	0.02	0.02	0.02
Santa Fe, N. Mex. [a]	0.03	0.05	0.04
Albany, N. Y	0.01	[b] 0.09	0.02
Gastonia, N. C	0.02	0.02	0.02
Oklahoma City, Okla. [a]	0.01	0.03	0.02
Ponca City, Okla	0.02	0.04	0.04
Portland, Ore. [a]	0.01	0.02	0.02
Harrisburg, Pa	0.01	0.02	0.01
Providence, R. I	0.01	0.02	0.02
Columbia, S. C	0.02	0.03	0.02
Pierre, S. Dak	0.02	0.02	0.02
Austin, Tex. [a]	0.01	0.02	0.01
El Paso, Tex	0.01	0.03	0.02
Salt Lake City, Utah	0.02	0.02	0.02
Richmond, Va. [a]	0.01	0.02	0.01
Seattle, Wash. [a]	0.01	0.02	0.02
Madison, Wis	0.01	0.02	0.02
Cheyenne, Wyo. [a]	0.01	0.02	0.02

[a] Stations used for averages in figure 1.
[b] High maximums due to faulty survey instruments.

Daily variations in external gamma activity at 21 representative RSN stations were studied next to determine whether they could be related to reported increases in fallout deposition. Since other studies (*4–6*) have shown that most world-wide fallout is deposited on the ground by means of precipitation and that very little reaches the earth as "dry fallout," an attempt was made to relate reports of gross beta activities from individual rainfalls and snowfalls to external gamma activities, measured directly during or after the period of precipitation. Data collected during the period from September 1961 through August 1962, when the RSN recorded relatively high precipitation activities were analyzed. Correlation coefficients[2] were computed by comparing gross beta activities in precipitation and external gamma activities (*7*). The results are presented in table 2.

The significance of each correlation coefficient was tested and it was found that correlations for only 5 of the 21 stations tested were statistically significant (i.e., different from zero) at the 95 percent confidence level (*7*). For two of these stations the correlation was negative (negative correlation indicates that, as activities in precipitation increase, the corresponding external gamma activities tend to decline). For practical purposes no clear relationship could be established between RSN external gamma measurements and fallout deposited by precipitation.

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[2] $$r = \frac{n\Sigma x_i y_i - (\Sigma x_i)(\Sigma y_i)}{\sqrt{n\Sigma x_i^2 - (\Sigma x_i)^2}\sqrt{n\Sigma y_i^2 - (\Sigma y_i)^2}}$$

Where: r=Correlation coefficient
n=Number of precipitation periods
y=Precipitation activity $\frac{(pc)}{(m^2)}$
x=External gamma activity $\frac{(mr)}{(hr)}$

As a final step in this study, a review of RSN data for the summer of 1957 was made to determine if excursions of gross beta activities in air samples at individual stations were accompanied by corresponding increases in external gamma levels. The summer of 1957 was chosen because it was during this period that the RSN reported the highest levels of gross beta activity in air and precipitation samples. There were several instances during this period when external gamma levels were found to increase with increases in gross beta levels in air, as at Boise, Idaho, Pierre, South Dakota, and Salt Lake City, Utah. The levels at Salt Lake City are shown graphically in figure 2. After 1957 no clear relationship between gross beta and external gamma levels was discerned.

TABLE 2.—COMPARISON OF PRECIPITATION DEPOSITION AND CORRESPONDING EXTERNAL GAMMA MEASUREMENTS, SEPTEMBER 1961–AUGUST 1962

Station	Number of precipitation samples	Average deposition nc/m²	Average external gamma mr/hr	Correlation coefficient
Juneau, Alaska	119	30	0.014	[a] 0.24
Little Rock, Ark	47	26	0.010	undefined
Berkeley, Calif	27	21	0.014	0.16
Washington, D. C	61	13	0.024	0.01
Jacksonville, Fla	52	10	0.012	0.03
Atlanta, Ga	32	16	0.026	0.18
Honolulu, Hawaii	35	9	0.026	[a] 0.44
Indianapolis, Ind	73	20	0.010	0.08
Iowa City, Iowa	66	18	0.019	0.04
Topeka, Kans	51	34	0.022	0.03
New Orleans, La	73	18	0.015	0.03
Lawrence, Mass	55	17	0.019	[a] −0.35
Minneapolis, Minn	74	15	0.011	[a] 0.43
Helena, Mont	49	14	0.030	0.17
Santa Fe, N. Mex	24	9	0.038	[a] −0.45
Albany, N. Y	58	7	0.028	0.04
Oklahoma City, Okla	17	8	0.017	0.41
Portland, Ore	70	19	0.020	0.02
Richmond, Va	59	18	0.011	0.01
Seattle, Wash	74	13	0.015	−0.12
Cheyenne, Wyo	38	13	0.021	−0.06

[a] Correlations that are statistically significant. (2σ).

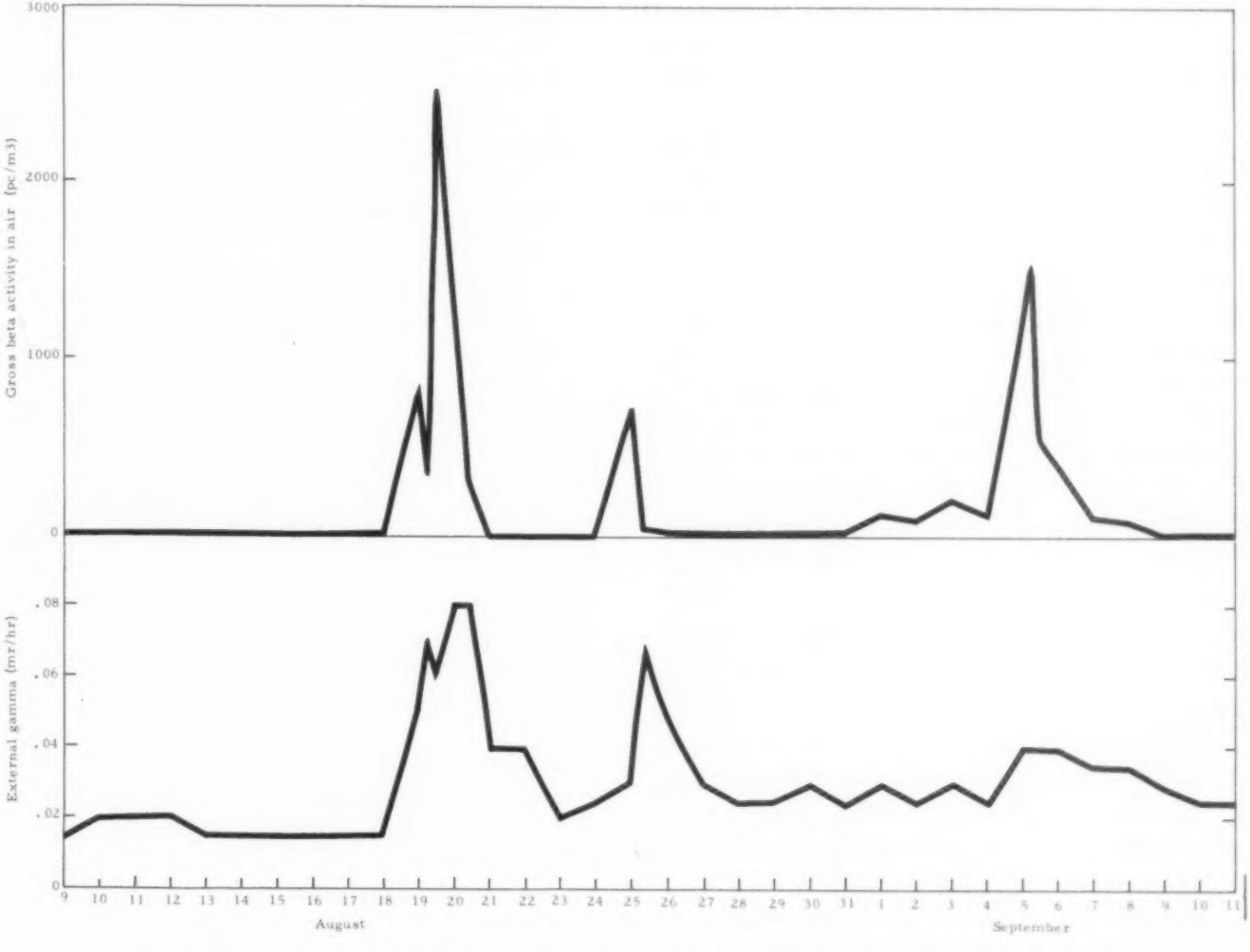

FIGURE 2.—GROSS BETA LEVELS IN AIR AND EXTERNAL GAMMA LEVELS AT SALT LAKE CITY, UTAH, DURING THE SUMMER OF 1957

Discussion

It can be deduced from the work of Knapp (*8*) and from a report by the U. S. Department of Defense (*9*) that external gamma increases approximately .001 mr/hr for every 30 nanocuries/m^2 of fallout deposited on the ground. Since few RSN stations have reported individual rainfall depositions in excess of 300 nc/m^2, only rarely would fallout deposition have been expected to have caused external gamma to increase by more than 0.01 mr/hr.

The RSN survey instruments are not sufficiently sensitive to measure small changes in external gamma activity. The normal range of external gamma measurements is from 0.01 to 0.04 mr/hr. These measurements are made at the extreme end of the lowest range of the survey meters. At such low readings, the manuals for the instruments claim an accuracy of ± 10 percent of the full scale or ± 0.02 mr/hr. Thus, a typical external gamma activity measurement of 0.02 mr/hr could be as much as 100 percent in error. This would tend to conceal small variations in monthly external gamma activity averages, and no definite correlation should be expected between external gamma measurements and precipitation deposition, as long as deposition levels remained below 300–600 nc/m^2.

Part of the lack of correlation between precipitation deposition and external gamma measurements may also have been due to the location of the external gamma measurements, since most were taken above hard surfaces such as rooftops. It is possible that much of the activity that was brought down by the rain was also washed off the surface by the same rain.

Summary

The RSN external gamma measurements are not effective indicators of fission product intrusions for the period 1959–1963. Instruments of greater sensitivity and different techniques of measurement would be needed to detect the small changes in external gamma activity associated with fallout deposited during this period. Since the present method is sensitive to such external radiation as experienced in the summer of 1957, it would seem advisable that the RSN continue these gamma measurements. The RSN is the only nationwide network presently making such measurements and it is conceivable that fallout on the order of one $\mu c/m^2$ could cause external gamma levels to increase by amounts such as those experienced in the summer of 1957.

Acknowledgement

The author gratefully acknowledges the statistical assistance of the Biometrics Unit of the Research Branch, Division of Radiological Health.

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Section II—Milk and Food

MILK SURVEILLANCE

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segment of the United States population and contains most of the radionuclides occurring in the environment which have been identified as biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to handle, is easily analyzed, and samples which are representative of milk consumption in any area can be readily obtained.

1. Pasteurized Milk Network July 1964

Division of Radiological Health and Division of Environmental Engineering and Food Protection, Public Health Service

The Public Health Service pasteurized milk surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of the raw milk network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this earlier network led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present network, which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico.

Sampling Procedure

Through the cooperation of State and local milk sanitation authorities, samples are routinely collected at each station. The method specifies that each station's sample be composited of subsamples from each milk processing plant in proportion to the plant's average sales in the community served. At most stations the sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of the community's supply as could be achieved under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then the sampling frequency has been reduced to once a week.

Samples are preserved with formaldehyde and are sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern Radiological Health Laboratories (NERHL) for analysis. Gamma analyses for iodine–131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pc/liter are immediately telephoned to State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after monthly samples are received by the laboratories; publication in *RHD* follows 3 to 4 months after the monthly samples are composited for analyses.

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Analytical Procedures

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectroscopy.[1] After the weekly samples are gamma scanned, samples from two consecutive weeks are composited and analyzed radiochemically for strontium–89 and strontium–90. There is an inherent statistical variation associated with all measurements of radionuclide concentrations. With the low radionuclide levels which are usually found in milk and other environmental samples, this variation on a percentage basis is relatively high. The variation depends upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclides and the background count. For milk samples, counting times of 50 minutes for gamma spectroscopy and 30 to 50 minutes for beta determinations are used. Table 1 shows the approximate total analytical error (including counting error) associated with radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. Table 1 gives the 95% confidence limits between which the true concentrations of the selected radionuclides might be expected in the analyses. The minimum detectable concentration is defined as the measured concentration at which the two-standard-deviation analytical error is equal to the measurement. Accordingly, the minimum detectable concentrations in units of pc/liter are Sr^{89}, 5; Sr^{90}, 2; Cs^{137}, 10; Ba^{140}, 10; and I^{131}, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

TABLE 1.—ANALYTICAL ERRORS ASSOCIATED WITH ESTIMATED CONCENTRATIONS FOR SELECTED RADIONUCLIDES IN MILK

Nuclide	Estimated concentration (pc/liter)	Error [a] (pc/liter)	Estimated concentration (pc/liter)	Error [a] (percent of concentration)
Iodine-131	0 to 100	±10	100 or greater	±10%
Barium-140	0 to 100	±10	100 or greater	±10%
Cesium-137	0 to 100	±10	100 or greater	±10%
Strontium-89	0 to 50	±5	50 or greater	±10%
Strontium-90	0 to 20	±2	20 or greater	±10%

[a] Two standard deviations (2σ).

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used. Stable potassium concentrations are estimated from the potassium–40 concentrations determined from the gamma spectrum.[2]

Data Presentation

Table 2 presents summaries of the analyses for July 28, 1964–July 25, 1964. Although not shown in table 2, the iodine–131 and barium–140 monthly average concentrations in milk were less than 10 pc/liter. Radionuclide values reported by a laboratory as being below the minimum detectable concentration have been averaged by using one-half the minimum detectable value. The averaging procedure was modified for iodine–131 and barium–140 in October 1963 when nondetectable concentrations of these radionuclides were considered zero. A similar procedure is used for the network average.

Figures 1 and 2 are isogram maps showing the estimated strontium–90 and cesium–137 concentrations in milk over the entire country. The value printed beside each station is the monthly average concentration for that station. The isograms were developed by arbitrary interpolation between values for the individual stations. Additional modifications to the isograms are made according to available information on milksheds.

In order to develop the distribution of the network's stations *versus* radionuclide concentrations in milk, table 3 has been prepared using monthly averages shown in table 2.

The average monthly strontium–90 concentrations in pasteurized milk from selected cities

[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium-140 analysis.

[2] The conversion factor is 1.18×10^{-3} g K/pc K^{40}.

TABLE 2.—STABLE ELEMENT AND RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, JULY 1964 [a] [b]

[Average radioactivity concentrations in pc/liter]

Sampling locations		Calcium (g/liter)		Potassium (g/liter)		Strontium-89		Strontium-90		Cesium-137		Last Sr^{90} graph in *RHD* (1964)
		Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	
Ala:	Montgomery	1.15	1.17	1.5	1.5	<5	<5	26	21	90	70	Oct
Alaska:	Palmer	1.22	1.15	1.4	1.5	5	<5	25	20	150	110	Nov
Ariz:	Phoenix	1.17	1.16	1.5	1.5	<5	<5	6	3	30	20	Sep
Ark:	Little Rock	1.15	1.16	1.5	1.5	<5	<5	58	40	160	90	Nov
Calif:	Sacramento	1.24	1.25	1.5	1.5	<5	<5	9	7	50	35	Aug
	San Francisco	1.22	1.19	1.4	1.5	<5	<5	12	8	55	40	Oct
Canal Zone:	Cristobal	1.09	1.11	1.5	1.6	<5	<5	6	4	55	50	Nov
Colo:	Denver	1.22	1.20	1.5	1.4	<5	<5	22	24	90	120	Aug
Conn:	Hartford	1.14	1.13	1.5	1.6	<5	<5	23	22	160	130	Aug
Del:	Wilmington	1.20	1.16	1.5	1.5	<5	<5	30	23	145	110	Sep
D. C:	Washington	1.12	1.11	1.6	1.5	<5	<5	23	22	100	80	Oct
Fla:	Tampa	1.13	1.18	1.5	1.6	<5	<5	15	17	260	260	Sep
Ga:	Atlanta	1.15	1.17	1.5	1.6	<5	<5	36	29	165	120	Oct
Hawaii:	Honolulu	1.16	1.19	1.6	1.5	<5	<5	11	10	85	70	Nov
Idaho:	Idaho Falls	1.21	1.27	1.4	1.5	10	<5	34	30	205	140	Sep
Ill:	Chicago	1.16	1.17	1.5	1.5	<5	<5	19	22	130	100	Oct
Ind:	Indianapolis	1.20	1.16	1.5	1.5	<5	<5	25	23	110	90	Aug
Iowa:	Des Moines	1.22	1.22	1.4	1.4	5	5	30	27	100	85	Sep
Kans:	Wichita	1.19	1.16	1.4	1.4	5	<5	25	21	80	60	Nov
Ky:	Louisville	1.13	1.11	1.5	1.6	<5	<5	37	31	100	65	Sep
La:	New Orleans	1.18	1.18	1.5	1.6	<5	<5	59	52	180	125	Nov
Maine:	Portland	1.18	1.18	1.5	1.5	<5	<5	33	36	210	190	Sep
Md:	Baltimore	1.13	1.13	1.5	1.6	<5	<5	28	26	125	90	Sep
Mass:	Boston	1.18	1.15	1.6	1.5	<5	<5	38	41	245	210	Oct
Mich:	Detroit	1.17	1.13	1.5	1.5	<5	<5	21	21	120	110	Aug
	Grand Rapids	1.22	1.17	1.5	1.4	<5	<5	23	23	135	115	Sep
Minn:	Minneapolis	1.22	1.20	1.5	1.5	10	<5	37	34	160	140	Oct
Miss:	Jackson	1.22	1.22	1.5	1.5	<5	<5	53	40	125	90	Aug
Mo:	Kansas City	1.19	1.20	1.4	1.4	10	<5	32	32	100	65	Aug
	St. Louis	1.21	1.19	1.4	1.5	10	<5	28	29	95	70	Nov
Mont:	Helena	1.19	1.18	1.5	1.5	5	<5	32	27	195	130	Nov
Nebr:	Omaha	1.21	1.21	1.5	1.5	5	<5	30	30	105	80	Sep
Nev:	Las Vegas	1.20	1.19	1.5	1.5	<5	<5	10	8	90	55	Oct
N. H:	Manchester	1.19	1.19	1.5	1.6	<5	<5	33	36	250	250	Sep
N. J:	Trenton	1.16	1.11	1.5	1.4	<5	<5	23	23	135	105	Aug
N. Mex:	Albuquerque	1.19	1.19	1.5	1.5	5	<5	14	12	70	50	Nov
N. Y:	Buffalo	1.15	1.10	1.5	1.5	<5	<5	24	22	160	130	Aug
	New York	1.14	1.12	1.5	1.6	<5	<5	30	32	180	150	Oct
	Syracuse	1.16	[b] —	1.6	—	<5	—	23	—	160	—	Nov
N. C:	Charlotte	1.16	1.18	1.5	1.5	<5	<5	43	39	140	110	Nov
N. Dak:	Minot	1.20	1.18	1.5	1.5	15	15	72	63	175	185	Sep
Ohio:	Cincinnati	1.18	1.16	1.5	1.6	<5	<5	28	21	105	70	Aug
	Cleveland	1.18	1.12	1.5	1.5	<5	<5	25	23	135	115	Nov
Okla:	Oklahoma City	1.13	1.12	1.6	1.6	<5	<5	27	20	75	60	Oct
Ore:	Portland	1.26	1.23	1.4	1.4	10	5	40	33	190	205	Aug
Pa:	Philadelphia	1.17	1.12	1.5	1.6	<5	<5	25	21	140	105	Nov
	Pittsburgh	1.18	1.13	1.5	1.5	<5	<5	34	35	175	160	Nov
P. R:	San Juan	1.11	1.15	1.5	1.5	<5	<5	15	14	90	80	Nov
R. I:	Providence	1.17	1.13	1.5	1.5	<5	<5	27	25	180	165	Sep
S. C:	Charleston	1.16	1.16	1.5	1.6	<5	<5	35	27	145	100	Aug
S. Dak:	Rapid City	1.14	1.26	1.5	1.4	10	<5	48	62	155	165	Oct
Tenn:	Chattanooga	1.17	1.19	1.4	1.6	<5	<5	51	42	145	95	Oct
	Memphis	1.16	1.14	1.5	1.6	<5	<5	42	32	85	60	Sep
Tex:	Austin	1.11	1.12	1.6	1.4	<5	<5	10	8	45	25	Oct
	Dallas	1.12	1.14	1.5	1.6	<5	<5	22	18	70	50	Aug
Utah:	Salt Lake City	1.24	1.28	1.5	1.6	10	<5	30	28	195	180	Nov
Vt:	Burlington	1.18	1.11	1.5	1.5	<5	<5	30	29	190	150	Aug
Va:	Norfolk	1.13	1.13	1.5	1.6	<5	<5	28	25	110	90	Aug
Wash:	Seattle	1.21	1.22	1.5	1.4	10	<5	36	35	190	220	Oct
	Spokane	1.27	1.26	1.5	1.5	10	<5	29	30	155	140	Aug
W. Va:	Charleston	1.13	1.13	1.5	1.5	<5	<5	34	26	95	60	Oct
Wis:	Milwaukee	1.23	1.19	1.6	1.6	<5	<5	21	17	145	110	Sep
Wyo:	Laramie	1.22	1.20	1.4	1.4	15	<5	25	28	120	130	Sep
Network average		1.18	1.17	1.5	1.5	<5	<5	28.9	26.3	133	110	Nov 63

[a] The monthly average iodine-131 and barium-140 concentration at each station was <10 pc/liter.
[b] Dash indicates no sample collected

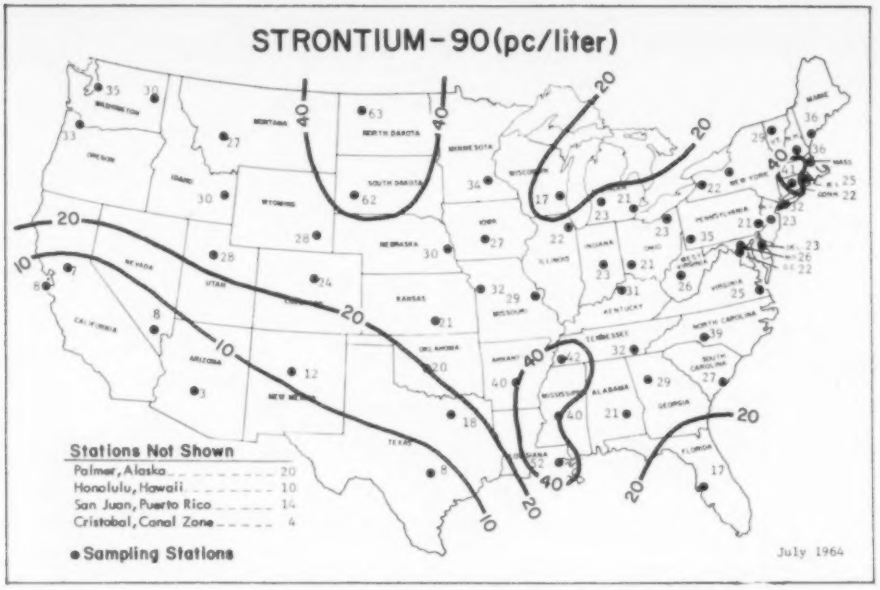

FIGURE 1.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK, JULY 1964

TABLE 3.—DISTRIBUTION OF SAMPLING STATIONS IN VARIOUS RANGES OF RADIONUCLIDE CONCENTRATIONS IN MILK, JULY 1964

Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
(pc/liter)	Number of stations	(pc/liter)	Number of stations	(pc/liter)	Number of stations	(pc/liter)	Number of stations	(pc/liter)	Number of stations
<5	59	<1-9	3	<10	62	<5-45	4	<10	62
5	2	10-19	7			50-95	24		
10	0	20-29	30			100-145	21		
20	1	30-39	16			150-195	8		
		40-49	4			200-245	3		
		50-59	1			250-295	2		
		60-69	1						

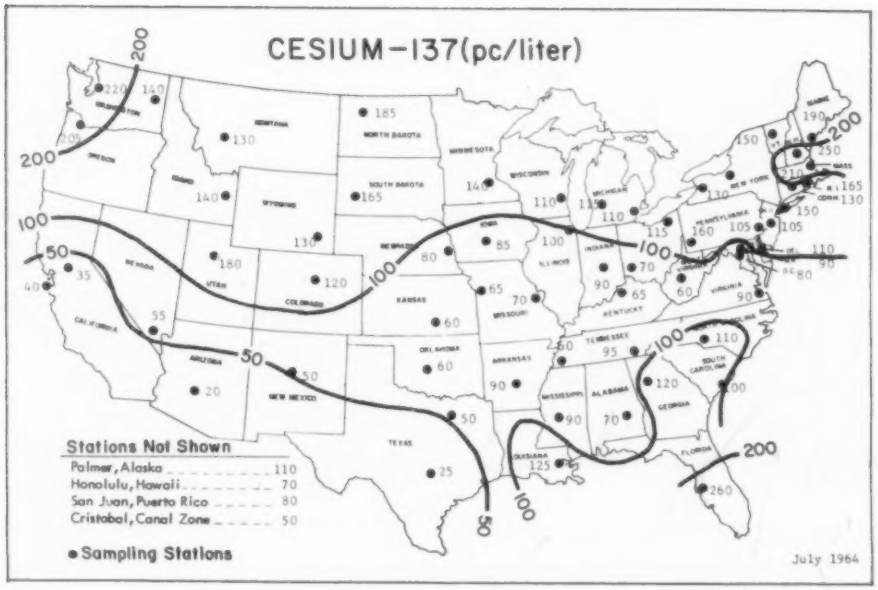

FIGURE 2.—CESIUM-137 CONCENTRATIONS IN PASTEURIZED MILK, JULY 1964

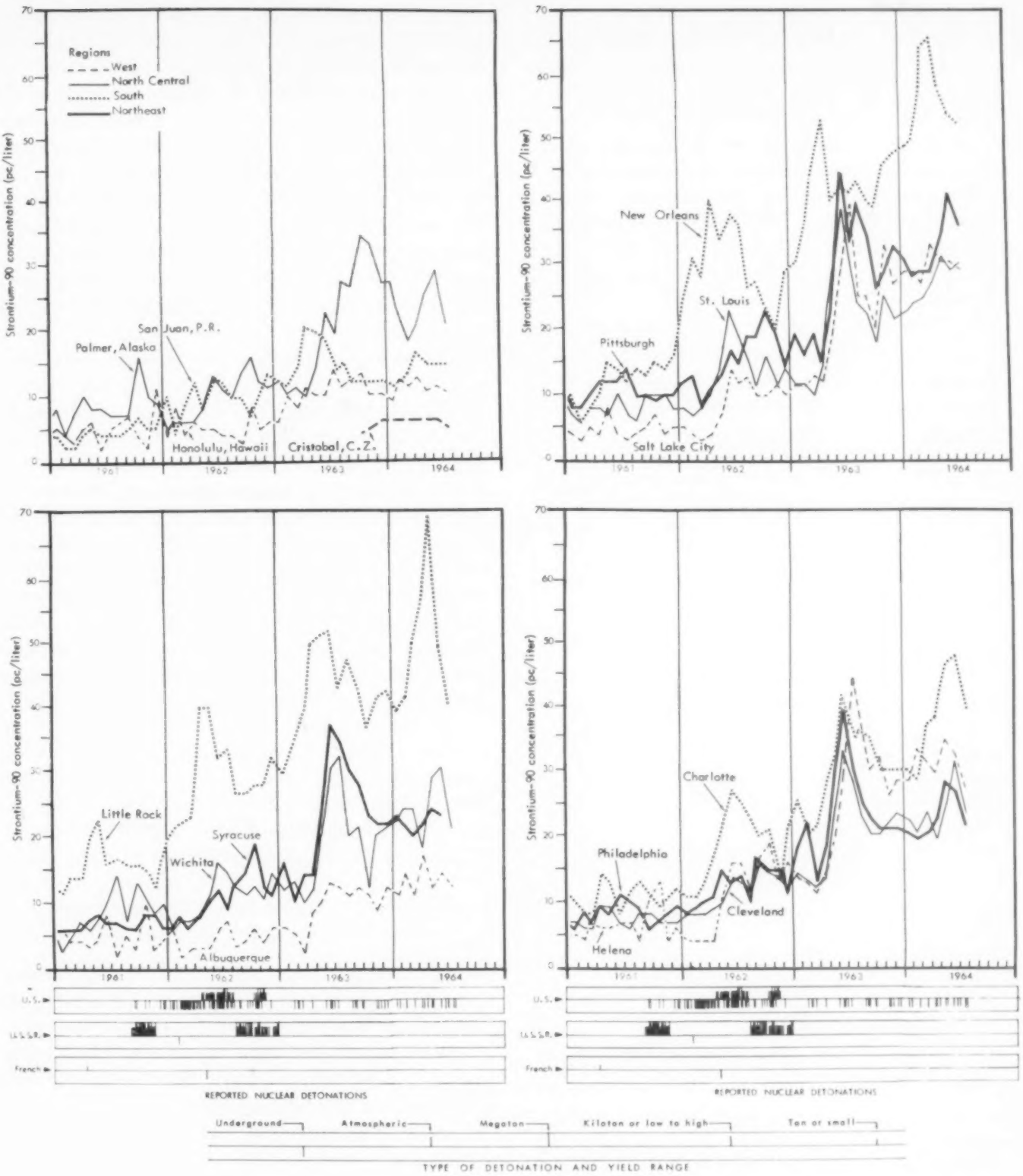

FIGURE 3.—STRONTIUM-90 IN PASTEURIZED MILK, 1961–JULY 1964

in the sampling program are presented in figure 3. Each graph shows the strontium–90 concentrations in milk from one city in each of the four U.S. Bureau of Census regions. This method of selection permits graphic presentation of data for each city in the network three times a year. The last column in table 2 shows the most recent issue in which a graph of the strontium–90 concentration was given for each station. A tabulation of the network monthly maximum, minimum, and average radionuclide concentrations in milk was given for March 1960–March 1964 in the July 1964 issue of *RHD* (*2*).

Figure 4 is a graph of the pasteurized milk network monthly averages for strontium–89, strontium–90, iodine–131, and cesium–137 from January 1961 through July 1964. The following discussion relates to this graph.

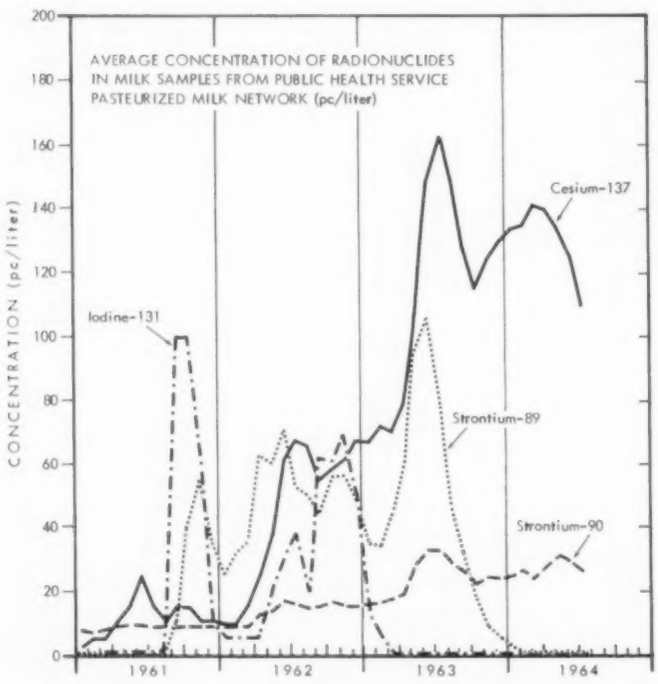

FIGURE 4.—NETWORK AVERAGE RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK

Strontium–90 concentrations in milk, which averaged about 10 pc/liter during 1961, gradually increased to 30 pc/liter by mid-1964. A peak extending into the high thirties during the spring and summer of 1963 is roughly 15 pc/liter above previous and subsequent averages.

Cesium–137 concentrations in milk averaged only about 5 pc/liter greater than strontium–90 concentrations during 1961. Unlike strontium–90, however, cesium–137 concentration increased rapidly to 60-70 pc/liter during the spring and summer of 1962. Again in the summer of 1963 cesium–137 in milk increased in concentration to 160 pc/liter. Thereafter, cesium–137 concentrations decreased to 120 pc/liter by July 1964. There was a decline in the cesium–137 concentrations during the summer of 1964 when concentrations dipped to about 115 pc/liter. In the three previous years the peak cesium–137 concentration occurred in mid-summer.

Iodine–131 concentrations in milk have been low or nondetectable except during September-December 1961 and May 1962 through January 1963. The maximum network average observed was 100 pc/liter.

The network average strontium–89 concentrations in milk rose above the minimum detectable limit of 5 pc/liter in October 1961 and remained there through 1962 and 1963. The maximum network average was 105 pc/liter. The variations in the network average which are apparent in figure 4 are due to such factors as the amount of nuclear testing and weather conditions as well as seasonal effects.

2. Indiana Milk Network
July 1964

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radiological analysis in September 1961. Indiana was geographically divided into five major milksheds, and one large dairy within each milkshed was selected as a sampling station (figure 5).

The milk samples are routinely analyzed for iodine–131, cesium–137, barium–140, strontium–89 and strontium–90. Until August 1963, analyses for the gamma emitters iodine–131, cesium–137 and barium–140 were conducted on a weekly basis, except when iodine–131 exceeded 100 pc/liter, at which times the frequency of sampling was increased. Because of

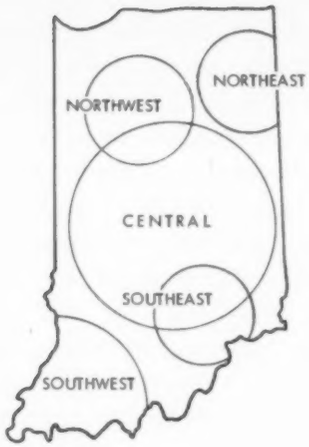

FIGURE 5.—INDIANA MILK SAMPLING LOCATIONS

continued low concentrations of the short-lived gamma emitters, the sampling frequency was reduced in August 1963 to once per month for the northeast, southeast and southwest milksheds. Strontium–89 and strontium–90 analyses are performed monthly for each station.

An ion exchange analytical procedure (*3*) is employed for strontium–89 and strontium–90 analyses. Minimum detectable levels for strontium–89 and strontium–90 are about 5 and 1 pc/liter, respectively. A 512-channel pulse height analyzer and shielded 4 x 4-inch sodium iodide crystal are used for the gamma analysis of iodine–131, cesium–137 and barium–140. Analyses of counting statistics indicate that the lower limit of detectability for both iodine–131 and barium–140 is 5 pc/liter. Cesium–137 analyses are subject to a 6 percent error at the 100 pc/liter level. Additional factors such as drift of the analyzer and calibration factors may increase these limits to a small extent.

The monthly averages of the data obtained for the individual sampling stations and the State averages are reported in table 4.

TABLE 4.—RADIONUCLIDES IN INDIANA MILK, JULY 1964 [a]

[Radionuclide concentrations in pc/liter]

Sampling location	Calcium (g/liter)	Potassium-40	Strontium-90	Cesium-137
Northeast	1.11	1,260	24	75
Southeast	1.12	1,330	25	70
Central	1.11	1,310	21	75
Southwest	1.12	1,320	22	70
Northwest	1.11	1,340	21	100
State average	1.11	1,310	23	80

[a] The monthly average iodine-131, barium-140, and strontium-89 concentrations at each station were zero.

3. New York Milk Network May 1964

Division of Environmental Health Services
State of New York Department of Health

Milk samples collected routinely from six cities—Albany, Buffalo, Massena, Newburgh, New York City, and Syracuse (figure 6) are analyzed for their radionuclide content by the State of New York Department of Health. Pasteurized milk samples are collected daily and composited weekly for the determination of strontium–89, strontium–90, iodine–131, cesium–137 and barium-lanthanum–140 at all stations except Massena, where samples are composited bi-weekly, and at New York City where one daily milk sample representing the

FIGURE 6.—NEW YORK MILK SAMPLING LOCATIONS

total milk supply for that day is obtained and analyzed once per week. Samples are obtained from processing plants except at Albany, where the daily sample is obtained from marketing point. During periods when cows are no longer on stored feed, the sample from Albany is analyzed daily for iodine-131. In the event that any city reports iodine–131 concentrations exceeding 100 pc/liter, increased surveillance is undertaken.

A matrix method (4) is used for the analysis of spectral data to determine the concentrations of gamma-emitting nuclides in milk. With this method, the individual nuclide contributions to the gamma spectrum are separated by solution of simultaneous equations describing the spectral interferences.

The analytical procedure for strontium–89 and strontium–90 is based on ion exchange methods. Cations (including radiostrontium) are eluted from the ion exchange resin with sodium chloride solution, strontium isotopes are gathered by means of sodium carbonate, isolated by means of ethylenediaminetetraacetic acid (EDTA), and radiostrontium is counted with a low background beta counter having an 0.8 mg/cm^2 window. The strontium–90 portion is differentially estimated by a second count 40 hours later to determine the rate of ingrowth of its daughter product yttrium–90. The monthly average radionuclide concentrations in milk are shown in table 5.

TABLE 5.—RADIONUCLIDES IN NEW YORK MILK, MAY 1964 [a]

[Average concentrations in pc/liter]

Sampling location	Strontium-89	Strontium-90	Cesium-137
Albany	<3	21	115
Buffalo	3	22	108
Massena	4	33	209
Newburgh	6	24	121
New York City	<3	25	118
Syracuse	4	25	108
Average	4	25	130

[a] The monthly average I^{131} and $Ba\text{-}La^{140}$ (in equilibrium) at each station was less than the minimum detectable level (20 pc/liter).

4. Oregon Milk Network March-May 1964

Division of Sanitation & Engineering, Oregon State Board of Health

The Oregon State Board of Health conducts milk monitoring at eight major milk-producing centers throughout the State of Orgeon, as shown in figure 7. Half-gallon samples of pasteurized packaged milk are collected Statewide on a monthly basis by the Oregon Department of Agriculture and weekly in the Portland area by the city of Portland. Milk sampling frequency is accelerated to a weekly schedule at those locations having radionuclide concentrations in milk in excess of 100 pc/liter for iodine–131 or 500 pc/liter for cesium–137. The samples are forwarded to the Oregon State Board of Health radiation laboratory for iodine–131, cesium–137, barium–140, and strontium–90 analyses. Gamma analyses are performed utilizing a 3″ x 3″ sodium iodide scintillation crystal detector with a 512-channel gamma spectrometer. Samples are normally counted for 100 minutes. The strontium–90 concentrations reported by the Oregon State Board of Health were analyzed using the trichloracetic acid analytical procedure (5) with the counting performed using a low background beta counter with a 2-inch detector. The minimum detectable concentrations for iodine–131, cesium–137, and barium–140 are 15 pc/liter. The minimum detectable concentration is defined to be that amount of activity which, in the same counting time, gives a count that differs from the background count by 3 times the standard deviation (σ) of the background count.

TABLE 6.—RADIONUCLIDE CONCENTRATIONS IN OREGON MILK, MARCH–MAY 1964 [a]

[Average concentrations in pc/liter]

Sampling location & frequency	Nuclide	March	April	May
Baker	Strontium-90	33	36	35
Monthly	Cesium-137	165	155	185
Coos Bay	Strontium-90	[b]—	84	53
Monthly	Cesium-137	—	260	190
Eugene	Strontium-90	28	31	19
Monthly	Cesium-137	130	120	160
Medford	Strontium-90	28	29	18
Monthly	Cesium-137	140	175	85
Nyssa	Strontium-90	28	18	23
Monthly	Cesium-137	135	110	125
Portland composite	Strontium-90	20	30	37
Weekly	Cesium-137	146	185	
Portland local producer	Strontium-90	27	32	50
Weekly	Cesium-137	173	170	197
Redmond	Strontium-90	26	25	18
Monthly	Cesium-137	160	180	105
Tillamook	Strontium-90	34	41	73
Weekly	Cesium-137	180	175	388

[a] Iodine-131 and barium-140 concentrations were below lower limit of detection of 15 pc/liter. In some cases unidentified activity having a half-life of about 5 days (suggested to be radon) interfered with some iodine-131 analyses.
[b] Dash indicates no analysis performed.

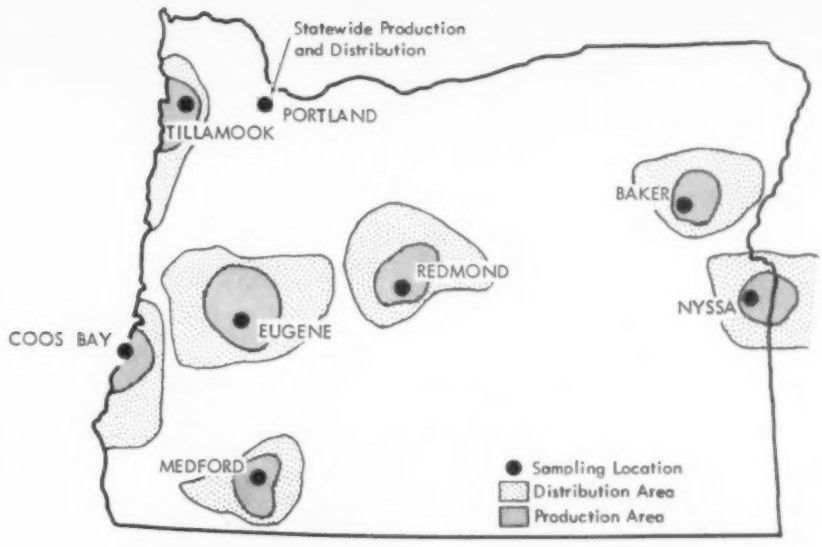

FIGURE 7.—OREGON PASTEURIZED MILK NETWORK SAMPLING LOCATIONS SHOWING PRODUCTION AND DISTRIBUTION AREAS

Table 6 presents the Oregon milk surveillance data for the period March through May 1964. The Portland composite sample represents contributions from nearly all milksheds in Oregon, plus some in southern Washington. Thus, it tends to represent a State average.

5. Canadian Milk Network [3] 1964

Radiation Protection Division
Department of National Health and Welfare,
Ottawa, Canada

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium–90 in November 1955. At first analyses were carried out on samples of powdered milk obtained from processing plants. However, since January 1963 liquid whole milk has been analyzed instead. With this change, more representative samples of milk consumed can be obtained, and in addition it is possible to choose milk sampling locations (see figure 8) in the same areas as the air and precipitation stations. At present, the analyses include determinations of iodine–131, strontium–89, cesium–137, and strontium–90 as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station samples are collected three times a week from selected dairies and are combined into weekly composites and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine–131. The results of the spot checks for iodine–131 will not be reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium–90, cesium–137, and stable potassium and calcium.

[3] Data from *Radiation Protection Programs, Vol. 2, No. 8:* 25-30, Radiation Protection Division, Canadian Department of National Health and Welfare (July 1964).

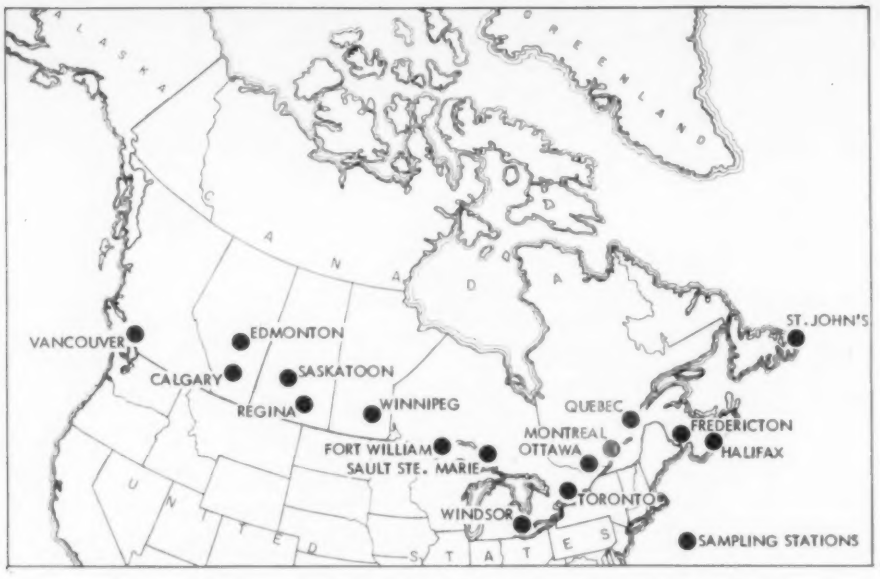

FIGURE 8.—CANADIAN MILK SAMPLING STATIONS

Analytical Methods

Radiochemical methods are used for the analysis of iodine–131 (*6*). For the analysis of radiostrontium, carrier strontium is added to a one-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet and evaporated under infra-red lamps. The residue is ashed in a muffle furnace at 450° C, dissolved in dilute nitric acid, and strontium separated by fuming nitric acid precipitation. The combined strontium–89 and strontium–90 are determined by counting in a low background beta counter. Strontium–90 is determined separately by extracting and counting the yttrium–90 daughter while strontium–89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption and counter efficiency at all stages. Calcium is determined by flame photometry.

Cesium–137 is determined by gamma spectroscopy using a scintillation crystal and a multi-channel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accommodate the 5- x 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum recorded. Estimates are made of the potassium–40 and cesium–137 content of the milk by comparison of the spectrum with the spectra of standard preparations of these two radionuclides. With this method the pottassium–40 concentration is determined and the Compton contribution of this radionuclide to the cesium–137 photopeak is subtracted to obtain the cesium–137 concentration. The stable potassium content is estimated from the potassium–40 concentration.

Sources of Error

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is about plus-or-minus 10 percent. This value is independent of the concentration of the radioisotope in the milk because it depends only on the recovery of the carrier. In the determination of cesium–137 this factor is not involved.

The chemical procedures error must be combined with the counting error which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated mathematically for the particular counting arrangement used.

The overall errors, estimated on the basis indicated above, are given in table 7.

TABLE 7.—TOTAL ERROR FOR VARIOUS RADIONUCLIDE CONCENTRATIONS IN MILK [a]

Nuclide	Error for 10 pc/liter	Error for 50 pc/liter	Error for 100 pc/liter
Strontium-89	±25%	±20%	±15%
Strontium-90	±15%	±10%	±10%
Iodine-131	±50%	±20%	±10%
Cesium-137	±60%	±25%	±10%

[a] All errors are 2σ values, representing 95 percent confidence levels.

TABLE 8.—RADIONUCLIDES IN CANADIAN WHOLE MILK, JUNE 1964

[Radionuclide concentration in pc/liter]

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90	Cesium-137
Calgary	1.13	1.6	30.7	142
Edmonton	1.13	1.5	32.1	160
Ft. William	1.13	1.7	46.1	238
Fredericton	1.10	1.7	46.9	297
Halifax	1.15	1.7	57.7	346
Montreal	1.08	1.7	29.3	154
Ottawa	1.10	1.6	25.5	139
Quebec	1.10	1.6	47.2	251
Regina	1.10	1.7	36.4	146
St. John's, Nfld.	1.08	1.6	73.0	402
Saskatoon	1.10	1.6	31.2	126
Sault Ste. Marie	1.08	1.6	44.0	233
Toronto	1.10	1.6	15.4	103
Vancouver	1.17	1.6	48.1	373
Windsor	1.08	1.6	16.0	95
Winnipeg	1.08	1.7	26.4	135
Average	1.11	1.6	37.9	209

Results

Table 8 presents monthly averages of strontium–90, cesium–137 and stable calcium and potassium in Canadian whole milk. Spot checks for iodine–131 and strontium–89 indicate that all samples had <5 pc/liter.

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MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, AUGUST 1963–JULY 1964

Division of Radiological Health, Public Health Service

Radionuclide concentration values reported by the Pasteurized Milk Network (*1*) can be used to estimate the contribution of milk to a population's radiation exposure. This is done by determining both the annual average concentrations of specific radionuclides in milk and the average daily milk consumption of a representative individual in a suitable sample of the population.

The data listed in table 1 are concerned with the first of these requirements, *i.e.,* annual average concentrations of strontium–89, strontium–90, and cesium–137 in one liter of pasteurized milk. Limited data are available for estimating the average daily milk consumption (on a volume basis) for specific age groups in the U.S. population (*2, 3*).

To arrive at a basis of comparison between the daily rates of intake of the radionuclides from the milk component of the diet and the Federal Radiation Council's ranges of transient daily rates if intake (*4*), it is assumed that the average daily milk consumption of an individual in a population group is one liter. The Guides, however, apply to total intake from all

TABLE 1.—MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN MILK[a,b]

[Concentrations in pc/liter]

Sampling locations		Strontium-89		Strontium-90		Cesium-137	
		July 1963–June 1964	August 1963–July 1964	July 1963–June 1964	August 1963–July 1964	July 1963–June 1964	August 1963–July 1964
Ala:	Montgomery	14	10	23	23	91	89
Alaska:	Palmer	20	16	26	26	164	164
Ariz:	Phoenix	3	3	4	4	26	26
Ark:	Little Rock	31	21	46	46	157	151
Calif:	Sacramento	5	4	9	9	56	55
	San Francisco	8	6	11	10	65	63
Colo:	Denver	14	10	20	20	94	93
Conn:	Hartford	13	10	25	24	182	173
Del:	Wilmington	12	9	26	26	145	140
D. C:	Washington	15	9	20	20	99	94
Fla:	Tampa	9	7	15	15	246	246
Ga:	Atlanta	23	15	33	33	159	149
Hawaii:	Honolulu	6	5	11	11	83	82
Idaho:	Idaho Falls	27	18	30	29	189	183
Ill:	Chicago	10	7	21	21	128	124
Ind:	Indianapolis	13	9	23	23	110	108
Iowa:	Des Moines	19	13	27	27	98	98
Kans:	Wichita	14	9	23	22	75	72
Ky:	Louisville	30	19	35	34	113	106
La:	New Orleans	25	16	50	50	161	157
Maine:	Portland	19	14	35	34	242	233
Md:	Baltimore	19	12	23	23	123	116
Mass:	Boston	22	16	38	37	271	265
Mich:	Detroit	10	8	20	20	127	126
	Grand Rapids	11	9	22	22	138	136
Minn:	Minneapolis	27	19	35	35	168	163
Miss:	Jackson	26	16	41	42	120	116
Mo:	Kansas City	21	15	29	30	90	89
	St. Louis	17	11	24	24	93	90
Mont:	Helena	27	16	33	31	217	205
Nebr:	Omaha	21	14	28	28	106	102
Nev:	Las Vegas	10	8	12	11	87	83
N. H:	Manchester	19	14	36	35	286	276
N. J:	Trenton	12	9	21	21	137	130
N. Mex:	Albuquerque	8	6	12	12	56	56
N. Y:	Buffalo	13	9	23	23	161	159
	New York	19	13	32	31	193	190
	Syracuse	15	11	24	24	161	161
N. C:	Charlotte	25	15	35	35	129	123
N. Dak:	Minot	38	24	61	61	163	162
Ohio:	Cincinnati	14	9	26	25	104	100
	Cleveland	13	8	23	22	125	124
Okla:	Oklahoma City	16	10	24	24	82	78
Ore:	Portland	21	15	33	33	177	178
Pa:	Philadelphia	12	7	23	22	136	132
	Pittsburgh	18	11	32	32	171	168
P. R:	San Juan	11	7	13	13	80	77
R. I:	Providence	14	9	28	27	191	184
S. C:	Charleston	13	7	30	31	140	135
S. Dak:	Rapid City	35	23	45	45	169	166
Tenn:	Chattanooga	33	20	43	42	149	136
	Memphis	22	13	34	33	87	81
Tex:	Austin	7	4	10	9	47	45
	Dallas	12	8	21	20	76	74
Utah:	Salt Lake City	22	15	28	27	194	187
Vt:	Burlington	18	13	31	30	213	206
Va:	Norfolk	14	9	23	23	106	102
Wash:	Seattle	22	15	29	29	167	167
	Spokane	23	16	31	30	155	152
W. Va:	Charleston	26	16	30	29	102	95
Wis:	Milwaukee	10	7	20	19	143	141
Wyo:	Laramie	20	14	23	22	118	117
Network average		18	12	26.8	26.4	136	132

[a] Annual averages were computed on basis of 52 weekly averages.
[b] Annual averages for iodine-131 and barium-140 at each station were <10.

sources. The upper limits of Range II correspond to the Radiation Protection Guide (RPG) for iodine–131 and to one-third of the RPG for radioactive strontium. The Guides are, for administrative reasons, expressed as a yearly radiation dose, but are based on lifetime exposure (*5*). The FRC emphasizes that the annual acceptable risk or exposure dose is not a dividing line between safety and danger in actual radiation situations (*6*).

Annual averages of radionuclide concentrations in milk sampled by the PHS Pasteurized Milk Network are presented in table 1. The data in table 1 are calculated as follows: Results from all samples collected in each week (Sunday through Saturday) are averaged, and the averages for all weeks terminating in each of twelve consecutive months are averaged to obtain the annual average.[1] To obtain the annual average daily intake (pc/day) of radionuclides from milk, the annual average concentration values (pc/liter) in table 1 must be multiplied by the annual average daily consumption (liters/day) of milk.

Monthly variations of radionuclide concentrations in milk are influenced by a number of combined causes such as weather conditions and dairying practices. The moving yearly average (table 1), obtained by updating the previous twelve-month average by one month, shows variations averaged over the year and tends to minimize purely seasonal variations. This method, therefore, shows trends over a considerable period of time.

[1] Beginning with the October 1963 data, iodine-131 values of <10 pc/liter are considered to be zero for averaging purposes; previously, 5 pc/liter was used for calculating the averages.

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STRONTIUM-90 CONTENT OF HUMAN FOOD AND ANIMAL FEED IN 1962 AND 1963

Division of Pharmacology
Food and Drug Administration

This report summarizes the findings of strontium–90 in human food and animal feeds harvested during 1962 and 1963. In contrast to the first resume report that appeared in the September 1963 *RHD* in which strontium–90 levels in food were compared in pre- and post-atmospheric testing situations, this report attempts to assess the levels during 1962 and 1963 and to evaluate the trends. On the basis of meteorological prognostications, it was expected that foods harvested in 1962 would clearly reflect the impact of atmospheric testing. However, the findings in the September 1963 *RHD* resume report showed no extensive increase in fallout in foods harvested in the immediate post testing period that extended through 1962. In retrospect, it can now be seen that the prediction of a heavy fallout peak for the spring of 1962 erred on the high side by a considerable margin. There is evidence that a sizeable inventory of strontium–90 still exists in the atmosphere, but that the rate at which this reaches the earth's surface may be slower than was anticipated. Thus instead of a sharp peak in 1962, it is expected that contamination will be spread out over a number of years and decline slowly.

This report represents a collation of 3,839 strontium–90 analyses made by 10 Food and Drug District Laboratories during 1962 and 1963. It does not include cesium–137 results because the numbers of analyses are too limited to be effectively interpreted. Quarterly analyses of total diet for strontium–90 and cesium–137 have been reported elsewhere. For details of sampling and analytical procedures, refer to the resume report in the September 1963 *RHD* (*1*).

Results

Table 1 gives the strontium–90 content of twelve food groups arranged to identify harvest years 1962 and 1963. With two minor exceptions (sea food and spices) the strontium–90 content of all food groups harvested in 1963 is higher. In some categories the rise is noteworthy, as exemplified by animal feeds and grains. In some groups where the disparity in number of samples in the two comparison periods is very great, caution should be used in the overall interpretation, limiting this merely to an indication of trends. (*cf.* root vegetables, fruits, tea, coffee, etc.)

TABLE 1.—STRONTIUM-90 CONTENT OF HUMAN FOODS AND ANIMAL FEEDS

[Concentrations in pc/kg]

Product	1962 Harvest				1963 Harvest			
	No. of varieties	No. of samples	Average	Range	No. of varieties	No. of samples	Average	Range
Animal feed	7	168	350	0.5—1700	5	102	1080	17 —6860
Coffee		114	16	0.9— 90		28	39	1.7— 99
Dairy products		72	118	4.8—1040		106	219	6.2— 736
Eggs		35	2.7	0.2— 9		8	5.2	2.6— 11
Fruits	17	541	5.2	0.0— 103	10	147	19	0.0— 102
Grains	6	271	66	0.5— 495	6	167	247	0.4—1340
Nuts	6	85	52	0.0— 292	3	36	144	0.5— 543
Root vegetables	7	352	12	0.0— 494	7	96	14	0.3— 157
Sea food	12	201	2.0	0.0— 43	3	10	1.0	0.1— 4.3
Spices	12	93	549	0.8—4400	3	7	199	1.7— 700
Tea		158	386	19 —2290		30	778	39 —4060
Vegetables	16	643	36	0.0— 927	14	369	45	0.4— 598

Tables 2 through 7 list in detail the strontium–90 content of five of the products: vegetables, root vegetables, fruits, grains and animal feeds. Here again, because of disparity in numbers of some varieties compared, trends can merely be indicative. However, in such items as lettuce, spinach, soybeans and cabbage (table 2) where the number of samples compared at least approaches the same order of magnitude, it can be seen that the increases in strontium–90 in 1963 are small. Similar trends may be noted in beets and carrots, (table 3) but a notable exception is white potatoes, where the increase has been more than three-fold. In the case of fruits sizeable increases are observed in strawberries, peaches and apples. In the grains, (table 5) the three-to four-fold increases in oats, wheat and barley are striking. The relatively low strontium–90 content of corn which has received frequent comment in the past, does not, however, indicate any upward trend in 1963; unfortunately, the numbers of samples examined in the two seasons are rather small. Table 6 points up the fact that the animal feeds, peanut hay, lespedeza hay and alfalfa, important sources of strontium–90 in the food chain, had sizable increases in the harvest year 1963.

It seemed of interest to determine whether the place of growth and harvest of foods within the continental U.S.A. would influence the levels of strontium–90. Three areas were selected, and all those foods having representation in number of samples of approximately the same order were tabulated. The areas are as follows:

TABLE 2.—STRONTIUM-90 CONTENT OF VEGETABLES

[Concentrations in pc/kg]

Variety	1962 Harvest			1963 Harvest		
	No. of samples	Average	Range	No. of samples	Average	Range
LEAFY						
Celery	74	12	0.7— 60	62	20	0.9—118
Collards	21	210	10 —688	9	49	5.0—201
Kale	5	121	22 —237	5	16	4.7— 27
Lettuce	125	17	0.1—178	120	22	1.1—141
Mustard greens	2	69	47 — 91	2	164	111 —217
Parsley	38	74	5.0—178	1	88	
Spinach	36	57	5.3—198	42	88	3.1—228
Turnip greens	9	222	2.8—927	1	484	
LEGUMES						
Peas	50	11	0.0— 53	2	11	7.2— 15
Soybeans	62	75	1.2—693	59	112	2.7—598
BRASSICAE						
Broccoli	28	33	0.7—244	2	2.3	1.3— 3.4
Brussel sprouts	6	5.7	0.7— 7.8			
Cabbage	127	13	0.3— 68	56	17	0.4—153
Cauliflower	30	4.6	0.9— 14			
MISCELLANEOUS						
Artichokes	6	21	1.4— 38	2	7.2	7.1— 7.2
Asparagus	24	2.0	0.2— 12	6	2.5	1.2— 3.4

Western States	Central States	Eastern States
Arizona	Alabama	Connecticut
California	Arkansas	Delaware
Colorado	Illinois	Florida
Idaho	Indiana	Georgia
Montana	Iowa	Maryland
Nevada	Kansas	Maine
New Mexico	Kentucky	Massachusetts
Oregon	Louisiana	New Hampshire
Utah	Michigan	New Jersey
Washington	Minnesota	New York
	Mississippi	North Carolina
	Missouri	Pennsylvania
	Nebraska	Rhode Island
	North Dakota	South Carolina
	Ohio	Vermont
	Oklahoma	Virginia
	South Dakota	West Virginia
	Tennessee	
	Texas	
	Wisconsin	

Table 7 shows the results of this arrangement. First, it can be seen that there is a clear trend, both in 1962 and 1963, for contamination to be lowest in the Western Region, highest in the Central Region, and intermediate in the Eastern region. Second, it can be seen that the individual averages for all products are higher in 1963 than in 1962. It follows therefore that the ratio of strontium–90 in 1963 to strontium–90 in 1962 is greater than unity. It is of interest, however, to observe that the average strontium–90 increase in 1963 has been highest in the West and lowest in the East. (See grand average of ratios table 7.) Statistical analyses show that the level of significance is 90 percent, indicating a well-defined trend.

The regional comparisons for 5 products (wheat, cabbage, potatoes, strawberries and alfalfa) are illustrated in figure 1.

Conclusions

1. There is a clear indication that the levels of strontimum–90 contamination in foodstuffs have risen in 1963 over 1962.
2. In both 1962 and 1963, the highest levels of strontium–90 were observed in the Central States and the lowest were observed in the Western States.

TABLE 3.—STRONTIUM-90 CONTENT OF ROOT VEGETABLES

[Concentrations in pc/kg]

Variety	1962 Harvest			1963 Harvest		
	No. of samples	Average	Range	No. of samples	Average	Range
Beets	60	15	0.7—104	38	17	0.4— 64
Carrots	79	7.6	0.3— 52	38	17	0.4— 64
Onions	48	8.1	0.0— 70	6	10	4.6— 26
Radishes	33	10	0.6— 92	1	22	
Sweet potatoes	38	39	2.3—494	3	9.0	1.8— 14
Turnips	19	11	0.9— 42	1	4.6	
White potatoes	75	2.3	0.0— 6.4	42	10	0.3—157

TABLE 4.—STRONTIUM-90 CONTENT OF FRUITS

[Concentrations in pc/kg]

Variety	1962 Harvest			1963 Harvest		
	No. of samples	Average	Range	No. of samples	Average	Range
Apples	50	2.3	0.1— 9.5	26	8.4	0.7— 22
Apricots	7	1.5	0.7— 2.9			
Cantaloupe	15	2.9	0.1— 24			
Cherries	59	5.3	0.2— 16	3	15	11 — 20
Cranberries	9	44	12 —103			
Cucumbers	39	5.8	0.4— 20			
Grapes	43	7.6	0.4— 50	4	33	16 — 56
Oranges	13	9.3	1.5— 27	3	11	1.9— 29
Peaches	43	5.2	0.2— 14	37	16	2 — 90
Pears	29	5.0	0.0— 14	3	21	4.6— 31
Peppers	27	2.3	0.1— 7.9			
Plums	29	2.1	0.3— 6.6			
Pumpkins	29	7.0	0.0— 40	2	9.6	8.1— 11
Squash	54	6.2	0.2— 34	3	6.1	1.8— 13
Strawberries	21	14	0.8— 42	45	32	2.7—102
Tomatoes	64	2.6	0.0— 9.0	21	6.5	0.0— 38
Watermelons	10	3.3	0.2— 15			

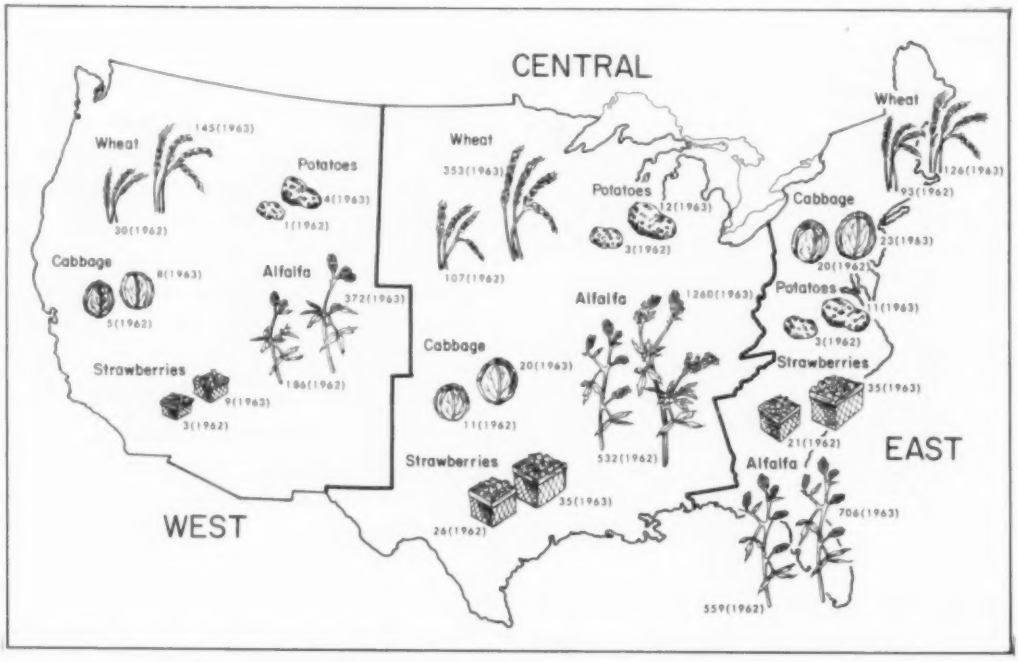

FIGURE 1.—STRONTIUM-90 CONTENT (pc/kg) OF FIVE SELECTED CROPS BY REGION, 1962–1963

TABLE 5.—STRONTIUM-90 CONTENT OF GRAINS

[Concentrations in pc/kg]

Variety	1962 Harvest			1963 Harvest		
	No. of samples	Average	Range	No. of samples	Average	Range
Barley	31	53	1.5—129	26	244	21 —868
Corn	31	2.5	0.5— 15	7	2.5	0.4— 5.2
Oats	38	61	0.9—187	20	173	10 —609
Rice	14	41	6.9—213	6	323	117 —544
Rye	19	103	6.2—255	19	212	13 —966
Wheat	138	83	1.4—495	89	286	4.0— 40

TABLE 6.—STRONTIUM-90 CONTENT OF ANIMAL FEEDS

[Concentrations in pc/kg]

Variety	1962 Harvest			1963 Harvest		
	No. of samples	Average	Range	No. of samples	Average	Range
Alfalfa	100	447	21 —1700	79	916	17—6860
Beet pulp	19	17	1.0— 196			
Corn ensilage	16	91	6.0— 378			
Cotton seed meal	10	23	0.5— 156			
Lespedeza hay	7	632	75 —1270	6	2427	178—3870
Peanut hay	9	740	25 —1640	15	1505	84—4320
Sorghum	7	117	9.0— 354	2	23	17— 28

TABLE 7.—REGIONAL CHANGES IN STRONTIUM-90 CONTENT OF PRODUCTS 1962 AND 1963 HARVEST

	Western States			Central States			Eastern States		
	1962	1963	Ratio [a]	1962	1963	Ratio [a]	1962	1963	Ratio [a]
ALFALFA									
No. of samples	27	18		44	41		29	20	
Average [b]	186	372	2.0	532	1257	2.4	559	706	1.3
APPLES									
No. of samples	14	8		15	10		21	8	
Average	0.9	4.0	4.5	2.8	11	3.9	3.0	9.4	3.1
CABBAGE									
No. of samples	26	19		48	23		53	14	
Average	5.0	8.0	1.6	11	20	1.8	20	23	1.1
CARROTS									
No. of samples	32	13		26	11		21	14	
Average	2.3	7.4	3.2	8.5	18	2.1	15	24	1.6
CELERY									
No. of samples	23	20		11	13		40	29	
Average	4.7	14	3.0	7.0	20	2.9	17	35	2.1
LETTUCE									
No. of samples	46	64		18	12		61	44	
Average	11	13	1.2	22	40	1.8	20	29	1.5
PEACHES									
No. of samples	10	10		9	11		24	16	
Average	1.7	5.1	3.0	9.4	25	2.7	5.1	17	3.3
SPINACH									
No. of samples	12	15		8	12		16	15	
Average	77	88	1.3	72	114	1.6	33	66	2.0
STRAWBERRIES									
No. of samples	10	5		5	24		6	16	
Average	3.0	9.1	3.0	26	35	1.4	21	35	1.7
TOMATOES									
No. of samples	17	8		26	7		21	6	
Average	0.5	2.6	4.9	2.2	4.9	2.2	4.9	14	2.9
WHEAT									
No. of samples	41	10		80	62		17	17	
Average	30	145	4.8	107	353	3.3	93	126	1.4
WHITE POTATOES									
No. of samples	23	9		26	22		26	11	
Average	1.0	4.4	4.4	2.8	12	4.3	2.9	11	3.8
Grand average of concentrations	29	55		108	313		66	100	
Grand average of ratios			3.1			2.5			2.1

[a] Ratio = $\frac{\text{Strontium-90 in 1963}}{\text{Strontium-90 in 1962}}$

[b] Units for all average values: picocuries strontium-90 per kilogram.

3. By region, the smallest rise in strontium–90 content of foodstuffs in 1963 over 1962 was in the East.
4. Within the frame of reference indicated by the Federal Radiation Council, this survey has uncovered no foods which, on the basis of daily intake of strontium–90, would approach, much less exceed the suggested daily limits of intake.

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Section III—Water

GROSS RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, MAY 1964

Division of Water Supply and Pollution Control, Public Health Service

Levels of radioactivity in surface waters of the United States have been monitored by the Public Health Service Water Pollution Surveillance System since its initiation in 1957. Beginning with the establishment of 50 sampling points, this system has expanded to 130 stations as of October 1, 1964. These are operated jointly with other Federal, State, and local agencies, and industry. Samples are taken from surface waters of all major U. S. river basins for physical, chemical, biological and radiological analyses. These data can be used for evaluating sources of radioactivity which may affect specific domestic, commercial, and recreational uses of surface water. Further, the system provides background information necessary for recognizing pollution and water quality trends and for determining levels of radioactivity to which the population may be exposed. Data assembled through the system and exact locations of sampling points are published in annual compilations (*1–7*).

Sampling Procedures

The participating agencies collect one-liter "grab" samples each week and ship them "as is" to the Surveillance System Laboratory in Cincinnati for analysis. Gross alpha and gross beta radioactivity determinations on the suspended and dissolved solids are performed as frequently as deemed necessary.

Presently, gross alpha and beta determinations are made on monthly composites of the weekly samples received from most stations. Weekly alpha and beta determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are also conducted at all newly established stations for the first year of operation.

Normally, samples are counted within two weeks following collection or within one week after compositing. The decay of activity is followed on each sample for which the first analysis shows unusually high activity. Also, if a recount indicates that the original analysis was questionable, values based on recounting are recorded. All results are reported for the time of counting and are not extrapolated to the time of collection.

Analytical Methods

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*8*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate)

TABLE 1.—RADIOACTIVITY IN RAW SURFACE WATERS, MAY 1964

[Average concentrations in pc/liter]

Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River:						
Pittsbugh, Pa	3	8	11	1	1	2
Animas River:						
Cedar Hill, N. Mex	56	16	72	5	1	6
Apalachicola River:						
Chattahoochee, Fla	7	13	20	0	0	0
Arkansas River:						
Coolidge, Kansas	223	82	305	31	28	59
Ponca City, Okla	72	31	103	4	1	5
Fort Smith, Ark	99	82	181	9	2	11
Little Rock, Ark	60	25	85	5	1	6
Pendleton Ferry, Ark	73	33	106	5	0	5
Atchafalaya River:						
Morgan City, La	195	28	223	48	0	48
Bear River:						
Preston, Idaho	0	24	24	0	2	2
Big Horn River:						
Hardin, Mont	375	42	417	56	6	62
Big Sioux River:						
Sioux Falls, S. Dak	19	58	77	0	5	5
Chattahoochee River:						
Atlanta, Ga	12	7	19	1	0	1
Columbus, Ga	100	9	109	11	0	11
Lanett, Ala	6	7	13	1	0	1
Chena River:						
Fairbanks, Alaska	5	14	19	1	0	1
Clearwater River:						
Lewiston, Idaho	11	7	18	1	0	1
Clinch River:						
Clinton, Tenn	3	8	11	0	<1	<1
Kingston, Tenn	7	85	92	0	0	0
Colorado River:						
Loma, Colo	253	31	284	28	3	31
Page, Ariz	4	39	43	<1	13	13
Boulder City, Nev	2	14	16	0	8	8
Parker Dam, Calif-Ariz	1	27	28	0	8	8
Yuma, Ariz	3	43	46	0	4	4
Columbia River:						
Northport, Wash	2	7	9	0	1	1
Wenatchee, Wash	4	8	12	0	0	0
Pasco, Wash	428	1,183	1,611	<1	<1	<1
McNary Dam, Ore	41	131	172	0	1	1
Bonneville, Ore	38	184	222	0	0	0
Clatskanie, Ore	44	103	147	1	1	2
Connecticut River:						
Wilder, Vt	0	12	12	0	2	2
Northfield, Mass	13	12	25	0	0	0
Enfield Dam, Conn	3	10	13	0	0	0
Cuyahoga River:						
Cleveland, Ohio	10	38	48	0	1	1
Delaware River:						
Martins Creek, Pa	3	10	13	0	0	0
Trenton, N. J	3	8	11	0	0	0
Philadelphia, Pa	10	8	18	1	0	1
Escambia River:						
Century, Fla	5	8	13	0	0	0
Great Lakes:						
Duluth, Minn	6	11	17	0	0	0
Sault Ste. Marie, Mich	0	9	9	0	0	0
Milwaukee, Wisc	2	8	10	0	0	0
Gary, Ind	3	5	8	0	0	0
Port Huron, Mich	1	7	8	0	0	0
Detroit, Mich	6	12	18	0	0	0
Buffalo, N. Y	13	20	33	1	0	1
Green River:						
Dutch John, Utah	0	32	32	0	3	3
Hudson River:						
Poughkeepsie, N. Y	4	12	16	0	0	0
Illinois River:						
Peoria, Ill	13	30	43	0	1	1
Grafton, Ill	4	27	31	1	2	3
Kanawha River: Winfield Dam, W. Va	0	5	5	0	0	0
Kansas River:						
De Soto, Kans	39	35	74	5	3	8
Klamath River:						
Keno, Ore	4	18	22	0	0	0
Little Miami River:						
Cincinnati, Ohio	6	14	20	0	0	0
Maumee River:						
Toledo, Ohio	4	24	28	1	2	3
Merrimack River:						
Lowell, Mass	3	12	15	0	0	0
Mississippi River:						
St. Paul, Minn	10	53	63	0	3	3
Dubuque, Iowa	13	24	37	0	0	0
Burlington, Iowa	19	27	46	1	1	2
E. St. Louis, Ill	37	23	60	3	1	4
Cape Girardeau, Mo	61	28	89	9	1	10
W. Memphis, Ark	28	22	50	4	1	5
Vicksburg, Miss	40	27	67	2	0	2
Delta, La	62	19	81	4	1	5
New Roads, La	29	19	48	2	<1	2
New Orleans, La	45	22	67	7	3	10
Missouri River:						
Williston, N. Dak	14	31	45	2	4	6
Bismarck, N. Dak	4	37	41	0	2	2
Yankton, S. Dak	7	39	46	0	5	5
Omaha, Nebr	73	27	100	9	5	14
St. Joseph, Mo	190	38	228	37	4	41
Kansas City, Kans	215	46	261	19	2	21
Missouri City, Mo	97	28	125	19	3	22
St. Louis, Mo	117	30	147	17	4	21
Monongahela River:						
Pittsburgh, Pa	1	5	6	0	0	0
North Platte River:						
Henry, Nebr	38	40	78	2	19	21
Ohio River:						
Toronto, Ohio	7	11	18	0	0	0
Addison, Ohio	2	12	14	0	0	0
Huntington, W. Va	4	9	13	1	0	1
Cincinnati, Ohio	4	10	14	0	0	0
Louisville, Ky	3	10	13	0	1	1
Evansville, Ind	11	8	19	1	0	1
Cairo, Ill	15	18	33	2	0	2
Ouachita River:						
Bastrop, La	13	33	46	1	0	1
Pend Oreille River:						
Albeni Falls Dam, Idaho	3	7	10	0	1	1
Platte River:						
Plattsmouth, Nebr	277	49	326	40	5	45
Potomac River:						
Williamsport, Md	2	11	13	0	0	0
Great Falls, Md	3	9	12	0	0	0
Washington, D.C	2	9	11	<1	0	<1
Rainy River:						
Baudette, Minn	9	46	55	0	0	0
International Falls, Minn	7	29	36	0	0	0
Raritan River:						
Perth Amboy, N. J. (5 ft. Below Surface)	3	10	13	0	3	3
Perth Amboy, N. J. (5 ft. Above Bottom)	1	14	15	0	3	3
Red River, North:						
Grand Forks, N. Dak	20	71	91	3	5	8
Red River, South:						
Denison, Tex	1	54	55	0	8	8
Index, Ark	46	35	81	6	1	7
Bossier City, La	24	29	53	2	0	2
Alexandria, La	61	25	86	14	0	14
Rio Grande River:						
Alamosa, Colo	5	27	32	0	2	2
El Paso, Tex	3	24	27	<1	8	8
Laredo, Tex	145	32	177	11	1	12
Brownsville, Tex	25	20	45	3	4	7
Roanoke River:						
John H. Kerr Resr/ Dam, Va	5	11	16	1	0	1
Sabine River:						
Ruliff, Tex	11	25	36	1	0	1
Sacramento River:						
Greens Landing, Calif	0	5	5	0	0	0
St. Lawrence River:						
Massena, N. Y	2	15	17	0	0	0
San Joaquin River:						
Vernalis, Calif	5	14	19	1	6	7
San Juan River:						
Shiprock, N. Mex	10	20	30	1	3	4
Savannah River:						
North Augusta, S. C	19	15	34	1	0	1
Port Wentworth, Ga	18	18	36	<1	0	<1
Schuylkill River:						
Philadelphia, Pa	5	5	10	1	0	1
Shenandoah River:						
Berryville, Va	5	9	14	0	0	0
Ship Creek:						
Anchorage, Alaska	1	7	8	0	0	0
Snake River:						
Ice Harbor Dam, Wash	0	10	10	0	0	0
Wawawai, Wash	10	8	18	0	0	0
Payette, Idaho			No	Report		
South Platte River:						
Julesburg, Colo	9	58	67	1	36	37
Spokane River:						
Post Falls Dam, Idaho	1	4	5	0	0	0
Susquehanna River:						
Sayre, Pa	2	5	7	0	0	0
Conowingo, Md	4	11	15	0	0	0
Tennessee River:						
Lenoir City, Tenn	1	7	8	0	0	0
Chattanooga, Tenn	6	15	21	<1	0	<1
Bridgeport, Ala	2	13	15	0	0	0
Pickwick Landing, Tenn	5	16	21	0	0	0
Tombigbee River:						
Columbus, Miss	7	9	16	1	0	1
Truckee River:						
Farad, Calif	2	7	9	0	0	0
Verdigris River:						
Nowata, Okla	21	35	56	1	1	2
Wabash River:						
New Harmony, Ind	28	21	49	2	1	3
Willamette River:						
Portland, Ore	2	3	5	0	0	0
Yakima River:						
Richland, Wash	1	9	10	0	3	3
Yellowstone River:						
Sidney, Mont	293	17	310	61	3	64
Maximum	428	1,183	1,611	61	36	64
Minimum	0	3	5	0	0	0

Note: These data are preliminary; reanalysis of some samples may be made and additional analysis not completed at the time of the report may become available. For final data, one should consult the network's Annual Compilation of Data (7).

FIGURE 1.—TOTAL BETA ACTIVITY (pc/liter) IN SURFACE WATERS, MAY 1964

and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8, which give a known count rate if the instrument is in proper calibration, are used for daily checking of the counters.

Results

Table 1 presents May 1964 results of alpha and beta analyses of U. S. surface waters. The stations on a river are arranged in the table according to their relative location on the river, the first station listed being closest to the headwaters. These data are preliminary. Replicate analyses of some samples as well as some analyses incomplete at the time of this report will be included in the system's "Annual Compilation of Data" (*7*). The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pc/liter. When all samples have zero pc/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5 the mean is reported as <1 pc/liter.

In order to obtain a geographical perspective of the radioactivity in surface waters, the numbers alongside the various stations in figure 1 give the May 1964 average total beta activity in suspended-plus-dissolved solids in raw water collected at that station. Results for the years 1957–1962 have been summarized by Weaver *et al.* (*9*).

Strontium–90 Determinations

Beginning in 1959, strontium–90 analyses of the total solids of surface waters were made quarterly on three-month composites of aliquots from weekly samples. Beginning in November 1962, the frequency of analysis was reduced to two quarterly samples per year at each sampling point except those stations immediately below nuclear installations, where quarterly analyses were continued. Floyd and Weaver summarized the strontium–90 results obtained from 1959 through 1963 in the August 1964 issue of *RHD* (*10*). The most recent strontium–90 results appeared in the October 1964 issue of *RHD* (*11*).

Discussion

The monthly dissolved beta activity averages exceeded 100 pc/liter only on the Columbia River. Of the six stations on the Columbia River, the four downstream from the Hanford Atomic Products Operations facility had averages of between 103 and 1,183 pc/liter.

The maximum monthly average dissolved alpha activity observed at all of the stations was 36 pc/liter. This activity is associated with dissolved natural surface minerals. Of all stations, four on different rivers had monthly average dissolved alpha activity greater than 10 pc/liter.

While there are no generally applicable standards for surface waters, the radioactivity associated with dissolved solids provides a rough indication of the levels which could occur in treated water, since nearly all suspended matter is removed by the treatment process (*12*). The Public Health Service Drinking Water Standards state that in the absence of strontium–90 and alpha emitters,[1] a water supply is acceptable when the gross beta concentration does not exceed 1,000 pc/liter (*13*).

[1] Absence is taken here to mean a negligibly small fraction of the specific limits of 3 pc/liter and 10 pc/liter for unidentified alpha emitters and strontium-90, respectively.

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(*1*) Division of Water Supply and Pollution Control, Public Health Service: *National Water Quality Network Annual Compilation of Data, PHS Publication No. 663, 1958 Edition*, Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402. Price $1.50.

(*2*) *Ibid.*, 1959 Edition. Price $1.75.

(*3*) *Ibid.*, 1960 Edition.[2]

(*4*) *Ibid.*, 1961 Edition.[2]

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(*6*) *Ibid.*, 1963 Edition (in press).

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(*13*) Public Health Service: *Drinking Water Standards, Revised 1962, Public Health Service Publication No. 956*, Superintendent of Documents, Government Printing Office, Washington, D. C. 20402 (March 1963), price 30 cents.

[2] Single free copies of this publication may be obtained from: Public Inquiries Branch, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C. 20201.

RADIOACTIVITY IN WATERS AND SEDIMENTS OF THE COLORADO RIVER BASIN, 1950–1963

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Part I. Historical Background

Collection and analysis of water and sediment samples from the Colorado River Basin for their radioactivity content have been carried out by the Public Health Service since 1950. The resulting data have made it possible to determine with a high degree of accuracy the influence of extensive uranium mining and milling operations upon the waters of the Basin. Uranium extraction operations have been conducted in the Basin since the early 1940's.

The purpose of this paper is to present a brief summary of the radioactivity found in surface water and sediment samples collected to date, and to present some conclusions regarding differentiation between natural radioactivity and radioactivity due to uranium mining and milling activities. Part I of the paper presents a historical summary of data collected before the beginning of the Colorado River Basin Water Quality Control Project. Parts II and III present a detailed summary of the radioactivity in surface water and sediment at specific locations throughout the Colorado River Basin as reported by the above-mentioned Project.

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Uranium-bearing ore, as it is delivered to the mill for processing may have a uranium content of 0.1 to 2 percent as U_3O_8, and generally averages about 0.25 percent (*1*). This uranium is present as uranium–238 and uranium–235, both of which are naturally-occurring parents of long chains of radioactive daughter products. The decay chain of uranium–238, known as the uranium series of elements, contains eight alpha-emitters and six beta-emitters and is of primary concern. Although the milling processes are designed to extract uranium from the ore, some small portion (1 to 10 percent) of the total uranium, along with various uranium daughters and extraneous material present in the ore, remains in the waste liquors and spent ore solids (*1*). These radionuclides represent a wide range of relative hazard. Radium–226, one member of the uranium series, is the most hazardous, with an $(MPC)_w$ of 3.3 pc/liter for the population at large (*2*). The additional fact that essentially the entire amount of the radium–226 present in the ore, which by any measure is very large relative to what are considered safe concentrations, will be contained in the mill wastes, provides the basis for directing major waste control efforts towards this radionuclide (*1*). It is generally true that effective control of radium–226 pollution from uranium mill process wastes precludes any dangerous contamination of receiving waters by other members of the uranium series (*1*).

In October 1950, eight river water samples in the vicinity of four operating uranium mills were collected by the Public Health Service and

analyzed for dissolved radium–226 (*3*). The results are shown in table 1. These limited data indicated the influence of waste discharges from these operating mills upon the river water.

TABLE 1.—DISSOLVED RADIUM-226 IN RIVER WATER SAMPLES COLLECTED UPSTREAM AND DOWNSTREAM FROM OPERATING URANIUM MILLS IN 1950

River	Dissolved radium-226 (pg/liter) [a]	
	Above mill	Below mill
Animas, Mill A	0.20	4.5
Colorado, Mill B	0.36	4.5
San Miguel, Mill D	0.13	16.9
San Miguel, Mill E	0.15	43.4

[a] pc is taken as equivalent to pg.

In September 1955, at the request of several State Departments of Health, the Public Health Service conducted a brief reconnaissance survey of the surface water contamination arising from uranium milling operations in the Colorado Plateau area (*4*). This survey was designed to indicate the extent of the situation and possible future waste control programs by the various Basin States. Single instantaneous samples of water, bottom sediments, and aquatic organisms (when present) were collected from streams in the vicinity of seven of the eight uranium mills then operating. The data for water and sediment are summarized in table 2.

The data from the 1955 survey indicated that the radioactivity in the waste discharges from uranium mills in the Colorado Plateau area varied widely. It was determined as a result of this survey that further investigation of the effects of waste discharges was desirable.

Accordingly, during 1956 a five-day survey was carried out (*5*) in the vicinity of the two mills exhibiting the greatest effects upon stream water and sediment. During this period representative sampling of water, sediment, and biological media was carried out. The data obtained on water and sediments immediately upstream and at several downstream locations are summarized in table 3.

TABLE 3.—GROSS ALPHA RADIOACTIVITY AND RADIUM-226 IN RIVER WATER AND SEDIMENTS NEAR URANIUM MILLS, 1956

Location, San Miguel River	Water [a]		Sediments	
	Gross dissolved alpha (pc/liter)	Soluble radium-226 (pg/liter)	Gross alpha (pc/gram)[b]	Radium-226 (pg/gram)[b]
Mill D: Immediately upstream	9	0.2	20	1.2
4.4 miles downstream	480	22	9,900	2,100
8.9 miles downstream	260	7.2	45	7.8
15.4 miles downstream	260	5.3	95	22.8
Mill E: Immediately upstream	—	—	10	0.7
2.3 miles downstream	180	76	1,950	730
4.9 miles downstream	100	53	1,200	260
11.2 miles downstream	90	88	310	92
20.8 miles downstream	80	65	430	114
29.4 miles downstream	130	50	75	16.8
38.1 miles downstream	50	32	100	24

[a] Average of 5 daily composites.
[b] pc and pg/gram ash weight.

TABLE 2.—GROSS ALPHA RADIOACTIVITY AND RADIUM-226 IN RIVER WATER AND SEDIMENT NEAR URANIUM MILLS, 1955

River and mill	Water				Sediment	
	Gross dissolved alpha (pc/liter)		Dissolved radium-226 (pg/liter)		Gross alpha (pc/gram)	
	Above mill	Below mill	Above mill	Below mill	Above mill	Below mill
Animas A	≈0	27	0.2	3.3	16	850
Colorado B	≈0	41	0.4	0.4	15	45
Colorado C	3	140	0.3	39	—	[a] (5,600)
San Miguel D	8	124	0.3	9.4	17	[a] 1,800 (6,600)
San Miguel E	—	2,160	—	86	—	2,400
South Creek F	31	28,500	0.3	81	—	3,200
San Juan G	10	0	0.2	0.3	13	10

[a] Number in parentheses refers to activity at uranium mill outfall.

The data from table 3 show a quite definite increase of dissolved radium–226 in the river immediately below each mill with a gradual decrease from maximum concentrations downstream from each mill. It is interesting to note the levels of radioactivity in bottom sediments proceeding downstream from each mill. In the case of mill "D" there is a rapid decrease resulting from occurrence of a flash flood about a month prior to sample collection. Below mill "E" the decrease was more gradual due to thicker and more extensive sediment deposits that were less susceptible to the scouring action of high flows.

These earlier data indicated clearly that a real water pollution problem was occurring, specifically that dissolved radium–226 concentrations were considerably above allowable levels in some cases. The 1962 Public Health Service Drinking Water Standards set the limit for radium–226 at 3 pg/liter for public water supplies (*6*). As a result, during the summer of 1958 and fall of 1959, extensive surveys of radioactive pollution of the Animas River (Colorado-New Mexico) were carried out. This was done under provisions of the Federal Water Pollution Control Act on the basis of a request by the State of New Mexico. Since details of these surveys are too numerous for presentation here, the reader is referred to the referenced reports (*7,8*). Information gained from these studies showed the levels which can result from radioactive pollution of the water environment and the various pathways through which such contamination may move. As a result of this work, the responsible mill on the Animas River promptly took measures to abate pollution with very satisfactory results.

Immediately following the Animas River studies, the Colorado River Basin Water Quality Control Project was organized with radioactivity studies being a major part of its early activities.

Part II

Based on the accumulated data on radioactive contamination of Colorado River Basin surface waters and river sediments, a conference on uranium milling wastes was held in October 1957 at Cortez, Colorado, attended by representatives of the States of Arizona, New Mexico, Colorado, and Utah and the U. S. Public Health Service. At this conference, a Radium Monitoring Network was suggested to provide needed continuous data on radioactivity contributed by uranium mining and milling operations to Colorado River Basin surface waters. The envisioned purpose of this network was to define both natural and industrial sources of radioactive pollution, and to measure either improvement or degradation of surface waters due to these contamination sources. Accordingly, a Radium Monitoring Network was established when the U.S. Public Health Service's Colorado River Basin Water Quality Control Project was organized in 1960 under provisions of the Federal Water Pollution Control Act. The network has since been expanded to 27 stations (figure 1), seven of which are automatic stations and the remainder grab sampling stations.

Depending upon the type of data required and physical location limitations encountered at each station, grab samples are collected one to six times weekly and automatic samplers collect a 21-ml sample every hour. At the Colorado River Basin Project Laboratory, the samples are composited into weekly or monthly composite samples, filtered through a 0.45 micron pore size membrane filter, and the filtrate analyzed for the desired radionuclides.

Radium–226, with the lowest $(MPC)_w$ of all radio nuclides (*9*) has been the radioactive contaminant of greatest concern in uranium mill discharges (*1*). Consequently initial and primary emphasis was placed on analysis of network samples for radium–226 only. In October 1963, uranium determinations were

FIGURE 1.—AVERAGE RADIUM-226 (pg/liter) IN SURFACE WATERS OF THE COLORADO RIVER BASIN, (JAN. 61–DEC. 63)

added and present samples are being gamma scanned and analyzed for lead–210, polonium–210, thorium, gross beta activity, and gross alpha activity in suspended solids. These determinations have been added to provide a more definitive picture of the total radioactivity in Basin waters resulting from uranium industry operations. Since only preliminary results have been obtained to date on these more recent determinations, these data are not presented in this report.

A sumary of radium–226 and uranium results obtained from the various Radium Monitoring Network stations over the reporting period (January 1961 through December 1963) is presented in table 4, and a summary of all samples collected is given in table 5. Background sampling stations listed are defined as those upstream from uranium mining and milling operations or other contamination sources such as the radium-bearing mineral springs near Glenwood Springs, Colorado.

TABLE 4.—RADIUM-226 AND URANIUM IN COLORADO RIVER BASIN SURFACE WATERS AT RADIUM MONITORING NETWORK STATIONS, JANUARY 1961–DECEMBER 1963.

Stations	Radium-226 (pg/liter)		Uranium (μg/liter)	
	Average	Median	Average	Median
Background Stations [a]				
Animas River: Durango, Colo	0.06	0.06	1.2	1.1
Gunnison River: above Gunnison, Colo	0.05	0.04	1.1	1.0
below Gunnison, Colo	0.04	0.04	1.9	1.6
San Juan River: above Farmington, N. M	0.07	0.06	3.2	3.3
San Miguel River: above Naturita, Colo	0.04	0.04	1.3	1.3
Tomichi Creek: above Gunnison, Colo	0.02	0.02	—	—
Non-background Stations				
Animas River: Colo.-N.M. State Line	0.32	0.25	4.4	2.6
Colorado River: DeBeque, Colo	0.19	0.17	3.6	4.2
Fruita, Colo	0.19	0.18	9.7	9.7
Lake Havasu	0.35	0.36	8.4	8.2
Lake Mead	0.33	0.32	7.9	7.9
above Moab, Utah	0.26	0.26	10	10
below Moab, Utah	0.45	0.31	12	12
Page, Ariz	0.25	0.25	9.1	8.6
Silt, Colo	0.19	0.18	2.9	3.1
Yuma, Ariz	0.17	0.16	8.4	8.3
Dolores River: Bedrock, Colo	0.48	0.49	14	11
Gateway, Colo	1.2	0.96	9.3	9.2
Green River: Green River, Utah	0.09	0.09	5.4	5.7
Gunnison River: Grand Junction, Colo	0.09	0.08	11	12
San Juan River: below Farmington, N. M	0.12	0.12	4.6	3.6
above Mexican Hat, Utah	0.14	0.14	8.4	8.1
below Mexican Hat, Utah	0.19	0.14	9.2	9.1
below Shiprock, N. M	0.12	0.11	15	15
San Miguel River: above Uravan, Colo	0.25	0.24	7.8	5.8
below Uravan, Colo	1.1	0.99	26	24
Yampa River: Maybell, Colo	0.09	0.09	2.8	2.4

[a] Background stations are those upstream from uranium mining and milling operations or other contamination sources.

In keeping with the philosophy of minimum exposure (*9*), the majority of the uranium processing mills in the Colorado River Basin have successfully maintained negligible radioactivity contributions to Colorado River Basin waters through their efforts to provide proper treatment and containment of milling waste products. Even at those mills where significant contributions have occurred since 1960, only 6 of the 930 individual composite samples analyzed for radium–226 have indicated concentrations above the currently accepted yearly average limit of 3 pg/liter for radium in drinking water (*6*). No network sampling station has exhibited an overall average above this limit and only two stations have sustained average radium–226 concentrations slightly above the 1 pg/liter suggested maximum desirable level for Colorado River Basin waters (*10*).

The effect of various uranium milling operations on radium–226 concentrations in surface waters is portrayed in figure 1 in the varying average concentrations shown at nonbackground stations throughout the Upper Basin. Once the various Upper Basin contamination sources have exerted their influence, the Lower Basin reservoirs exhibit an apparently stabilized average concentration of approximately 0.34 pg/liter. Some as yet undetermined factors reduce this to 0.17 pg/liter at Yuma, Arizona. The Radium Monitoring Network data indicate that radium–226 concentrations below 0.10 pg/liter in Colorado River Basin streams can be considered background levels, while concentrations above this level are indicative of contamination sources somewhere upstream.

TABLE 5.—SUMMARY OF RESULTS OF RADIUM-226 AND URANIUM IN COLORADO RIVER BASIN SURFACE WATERS, JANUARY 1961–DECEMBER 1963

Type of station	Radium-226			Uranium		
	Number of samples	Average concentration (pg/liter)	Range (pg/liter)	Number of samples	Average concentration (μg/liter)	Range (μg/liter)
Background stations	116	0.05	0.01–0.16	64	1.6	0.0–8.3
Non-background stations	814	0.41	0.01–7.2	544	11	0.0–150
All stations	930	0.37	0.00–7.6	608	10	0.0–150

A specific example of radium–226 contamination of river water by uranium milling operations is shown in figure 2. The graph illustrates the effect on the river of past operations through the continuing erosion into the river of residual tailings at a nonoperating uranium mill. The more pronounced effect of an operating mill discharging wastes to the river is evident in the higher concentrations recorded below the second mill.

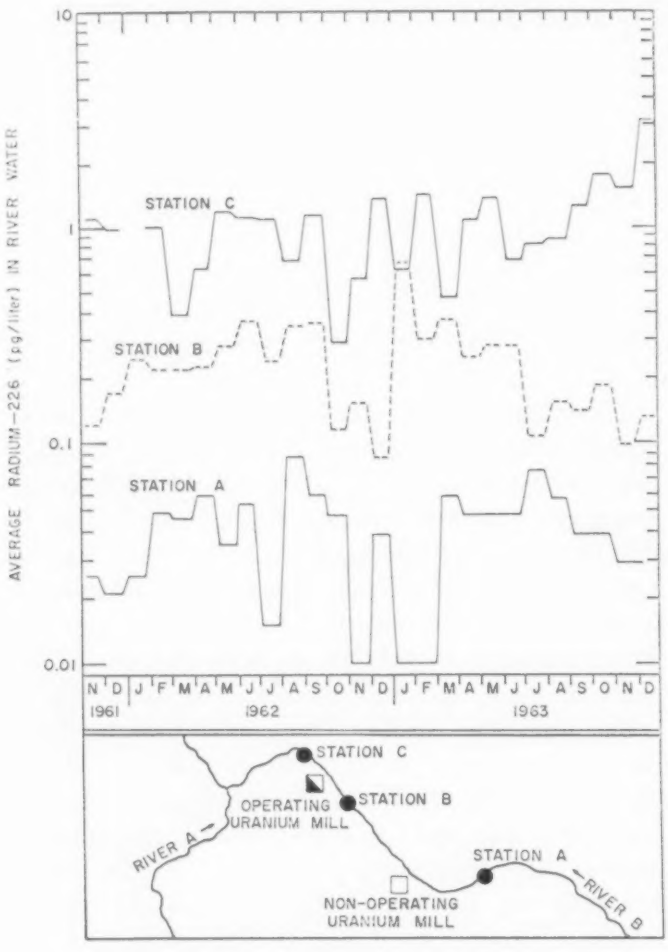

FIGURE 2.—EXAMPLE OF URANIUM MILL EFFECTS ON RADIUM–226 CONCENTRATIONS IN RIVER WATER

As portrayed in figure 2, once a uranium mill discontinues discharging waste products to a river, the radioactivity concentrations below the closed mill do not return to background levels immediately. Even if residual tailings do not reach the river, the assimilation of uranium milling wastes by stream sediments during mill operation can play an important part in the concentrations found in river water after contamination practices have ceased. It has been shown by both laboratory experiment and field studies that dissolved radium–226 levels in stream waters can depend to a large degree on the amount of radium–226 contained in the stream bed sediments, and that various hydraulic, physical and chemical factors govern the rate of release of the radium–226 to the overlying waters (*11*).

Preliminary data on radium–226 concentrations in river water coupled with bottom sediment records (see Part III) below uranium mills that have discontinued all waste releases to a river indicate that the rate of removal of radioactive sediment contaminants from a specific stream location is fairly slow. In one instance, a generalized slope drawn through plotted monthly averages of radium–226 concentration levels recorded in river water over a period of time show a drop from approximately 0.36 pg/liter in July 1961 to 0.16 pg/liter in December 1963. If this reduction continues at the same general rate, it will require a minimum of four years for concentrations at this particular station to return to background levels. One would expect the reduction rate to decrease as time passed, thereby requiring more than the estimated four years to attain background concentrations.

It should be emphasized that the sediment contaminant removal action referred to here pertains to only one specific location on the stream. Although radiation levels may be reduced at a given location over a period of time, the sediment contaminants originally producing the higher concentrations are continually being moved downstream to exert their cumulative influence at another location. This will more than likely be a reservoir or similar catch basin where the radioactivity-carrying sediments will ultimately accumulate (*11*).

It is obvious from the above discussion that knowledge of radium–226 concentration levels in river water at a given location in the Colorado River Basin can provide an excellent indication of intensities of radioactive contamination by uranium mining and milling operations. In addition, uranium concentrations in river water can also portray uranium mining or milling process contamination, but do not indicate degrees of contamination as reliably as does radium–226. This is to be expected, since uranium is the material being

recovered in the milling processes while radium–226 is always a waste product. Additionally, the effects of natural concentrations of uranium in stream bed deposits tend to vary widely with geographic location.

The rather high solubility of uranium and its readiness to form soluble complex ions (*12*) results in much higher leaching rates of uranium than of radium–226 from natural stream bed and watershed deposits. This is quite evident when the average uranium and radium–226 concentrations at background stations listed in table 4 are compared. The background station radium–226 activities average 4.9 percent of the uranium activities listed when compared on a curie basis. This means there are approximately 3×10^7 grams of uranium present in background waters for every gram of radium–226.[1]

This high solubility and subsequent concentration variations in water at different geographic locations makes it difficult to establish an average uranium concentration that can be designated as being typically background. Using the same stations classified in table 4 as background radium–226 concentrations, uranium levels below approximately 4 μg/liter would indicate background concentrations in the upper reaches of Colorado River Basin streams. Stations further downstream, however, show much higher concentrations which seemingly can be considered background. The Green River station at Green River, Utah, and the Gunnison River station at Grand Junction, Colorado, are both essentially background stations since they are downstream from uranium mills which release no significant contaminants to the streams. The radium–226 levels at these stations are at background, but the uranium levels of 5.4 and 11 μg/liter correspond to those found at other stations showing uranium mill contamination with radium–226 levels of three and four times background.

Uranium milling effects on uranium levels in Colorado River Basin waters are evident in table 4. The average level for nonbackground stations for the reporting period show 11 μg/liter as compared to the 1.6 μg/liter at the arbitrary background stations. The Lower Basin reservoirs exhibit an apparently stabilized concentration (similar to that observed for radium–226) near 8 μg/liter. The noted reduction in radium–226 concentrations at Yuma, Arizona, however, is not evident in the uranium concentrations. No Radium Monitoring Network sample has produced a uranium concentration above the suggested limit of 29,500 μg/liter.

Referring once again to the relationship between radium–226 and uranium concentrations in river water, table 6 is presented to show radium-uranium ratios (on a curie basis) found in Colorado River Basin waters. It seems noteworthy that the range of ratios is relatively narrow. This relationship can be utilized in obtaining a good idea of radium–226 concentrations, for instance, by determining the uranium concentration, or vice versa. From the knowledge of only one factor, additional relationships between radium in water and radium and gross alpha in sediment can be determined. These relationships are discussed in Part III.

TABLE 6.—RADIUM-226–URANIUM RATIOS IN COLORADO RIVER BASIN SURFACE WATERS, JANUARY 1961–DECEMBER 1963 [a]

Value	Background stations	Non-background stations	All stations
Average	0.049	0.047	0.048
Range	0.031–0.071	[b] 0.012–0.106	[b] 0.012–0.106

[a] The ratio is computed on a curie rather than on a weight basis.
[b] This range disregards an 0.190 ratio at Gateway, Colorado. If this higher figure is used, the average changes to 0.054 for non-background stations and 0.053 for all stations.

Part III. Basinwide Sediment Network

While radioactivity concentrations in water indicate immediate levels of contamination, algae, fish and other aquatic life are available as indicators of long term contamination levels in water. For ease of collection, sample preparation and analysis, stream and reservoir sediments have been shown to be the most desirable indicator medium.

[1] Uranium specific activity of 1.475×10^6 grams per curie was used here for computation purposes.

Therefore, when the Colorado River Basin Project was established, one of the first study programs initiated was the Basinwide Sediment Network. The objectives of this program have been to determine:

(a) the radioactivity levels in Basin River sediments;

(b) distribution of this radioactivity throughout the Basin;

(c) background levels versus levels below uranium mining and milling operations;

(d) effects of river hydrology on sediment deposition and transport.

For the first three sampling surveys (August 1960, March 1961, August 1961) the Basinwide Sediment Network consisted of 88 sampling stations. Examination of the data after the third survey indicated that the number of stations could be reduced without reducing the effectiveness of the program. Subsequently, the last four surveys (March 1962, September–December 1962, August 1963, March 1964) have been conducted using the present 30-station network.

Frequency and dates of sampling surveys have been designed to provide data on the effects of periodic flow changes. Colorado River Basin streams are typically unregulated, particularly in the Upper Basin, and most of the total annual flow occurs during late spring. The fall and winter low flow periods permit buildup of stream bed sediment deposits which are then effectively flushed downstream during spring and summer high flows. Sediment sampling dates, therefore, are scheduled in March, just before high flows carry the year's deposition downstream, and again in summer or fall after the flushing action has been completed.

Network samples are analyzed at the Colorado River Basin Project Laboratory for radium–226 and gross alpha activity. A summary of the analytical results is presented in table 7. These results suggest that hydrologic factors play their part in the low flow period buildup of contaminated sediments and the subsequent high flow channel scouring and sediment mixing. Radium–226 concentrations in the Upper Basin river sediments average higher in spring after the sediment buildup than the corresponding fall concentrations after the high spring and summer flows have removed a portion of the earlier deposition and mixed in a new load of uncontaminated sediments. Limited figures are available for gross alpha; however, these data also indicate the higher springtime concentrations.

The seasonal variations indicated by the Lower Basin river and reservoir sampling stations are not considered significant at this point, due to the relatively few samples collected. As more data are obtained, it is anticipated that the results will indicate essentially the same concentration levels the year round, resulting from the settling of sediments in the reservoirs and the subsequent stabilizing effect similar to that noted in Lower Basin water radioactivity.

Comparison of radium–226 concentrations found in pool sediments to those found in riffle sediments shows that while some of the pool sediments contained more radium than did riffle sediment, the data are generally not significantly different at a given location. In some cases, the riffle sediment contained more radium than the pool sediment (*11*). This leads to the conclusion that stream turbulance does not significantly affect sediment concentration levels at any specific location except in its role of moving sediments downstream.

Further examination of Basinwide Sediment Network data in table 7 provides several other observations regarding the distribution of radioactive sediments in the Colorado River Basin. Upper Basin background levels for radium–226 (above uranium mining and milling operations or other contamination sources) average 1.1 pg/gram of sediment while the overall average of non background stations in the Upper Basin is 2.3 pg/gram, showing the effect of the contamination sources. The Lower Basin reservoirs then exhibit their settling and collecting basin action, even with the relatively limited data available. Lake Mead sediments average 2.9 pg/gram (from 1960 and 1961 surveys), Lake Mohave averages 1.3 pg/gram,

TABLE 7.—RADIUM-226 AND GROSS ALPHA RADIOACTIVITY IN COLORADO RIVER BASIN SEDIMENTS, AUGUST 1960–MARCH 1964

Type of station and time period	Radium-226 (pg/gram)				Gross alpha (pc/gram)			
	No. of samples	Average	Median	Range	No. of samples	Average	Median	Range
Background stations								
Fall	43	1.1	1.1	0.3– 1.8	24	8	8	4– 14
Spring	14	1.3	1.2	0.6– 1.6	4	9	9	5– 14
Overall	57	1.1	1.1	0.3– 1.8	28	8	8	4– 14
Non-background station—upper basin								
Fall	143	2.1	1.5	0.5–14	103	15	11	2–100
Spring	77	2.7	1.5	0.4–14	33	22	12	5–140
Overall	220	2.3	1.5	0.4–14	136	16	11	2–140
Non-background stations—lower basin (river stations)								
Fall	13	0.7	0.8	0.3– 1.3	9	4	4	3– 20
Spring	5	0.6	0.4	0.4– 0.9	3	5	—	3– 9
Overall	18	0.7	0.6	0.3– 1.3	12	4	4	2– 20
Lake Mead [a]								
Overall	38	2.9	—	0.5– 5.5	21	16	—	7– 32
Lake Mohave								
Fall	7	1.2	1.2	0.6– 2.0	5	5	—	3– 13
Spring	3	1.5	—	0.9– 2.3	1	10	—	—
Overall	10	1.3	1.3	0.6– 2.3	6	6	—	3– 13
Lake Havasu								
Fall	9	2.3	2.2	1.5– 3.3	6	18	—	12– 24
Spring	4	2.0	—	1.8– 2.3	1	16	—	—
Overall	13	2.2	2.1	1.5– 3.3	7	18	—	12– 24
Imperial Reservoir								
Fall	9	0.8	0.8	0.3– 1.1	6	5	—	2– 10
Spring	4	0.5	—	0.4– 0.8	1	2	—	—
Overall	12	0.8	0.8	0.3– 1.1	7	5	—	2– 10

[a] From 1960–1961 Surveys (*13*) only.

and Lake Havasu averages 2.2 pg/gram. Imperial Reservoir at the lower end of the Colorado River exhibits background levels with 0.8 pg/gram. It is apparent from its higher concentrations that Lake Mead, being the first upstream reservoir, has been the primary collecting place for contaminated sediments. Now that Glen Canyon Dam has been completed, Lake Powell will take its place and become the primary final resting place for contaminated sediments.

The Lower Basin river stations indicate an overall average radium–226 concentration of 0.6 pg/gram of sediment, which is less than the observed background levels in the Upper Basin. It is apparent then that the lower Basin reservoirs collect practically all of the radioactive sediments carried down the Colorado River.

Gross alpha results indicate essentially the same radioactive sediment distribution pattern. Upper Basin background levels average 8 pc/gram of sediment and non-background stations produce a 16 pc/gram average. Lake Mead results from 1960 and 1961 surveys indicated a 16 pc/gram average, Lake Mohave indicated 6 pc/gram, Lake Havasu indicated 18 pc/gram, Imperial Reservoir indicated 5 pc/gram, and the Lower Basin river stations indicated 4 pc/gram. A disparity appears in both radium–226 and gross alpha results, wherein Lake Havasu averages are higher than those for Lake Mohave. Since Lake Mohave is further upstream, the opposite should be true. A possible explanation for this might be the presence of natural uranium deposits in some streams or dry washes in the immediate vicinity of Lake Havasu from which radioactive sediments could be obtained. However, this theory has not been substantiated.

Although the radium–226 and gross alpha results indicate generally the same distribution pattern of radioactive sediments, the concentration ratios between these factors do not remain proportional as one proceeds downstream. This is demonstrated in table 8.

Again, the Lake Havasu ratio is out of proportion to the pattern followed through the rest of the Basin. Ignoring this figure, however, the ratios show a systematic increase as one proceeds downstream, with the usual stabilization noted at Imperial Reservoir and the Lower Basin river stations.

TABLE 8.—RATIOS OF RADIUM-226 TO GROSS ALPHA IN COLORADO RIVER BASIN SEDIMENTS, AUGUST 1960–MARCH 1964

Station	Radium-226 pg/gram	Gross Alpha pc/gram	Ratio: radium-226/alpha
Upper Basin background stations	1.1	8	0.14
Upper Basin non-background stations	2.3	16	0.14
Lake Mead	2.9	16	0.18
Lake Havasu	2.2	18	0.12
Lake Mohave	1.3	6	0.22
Imperial Reservoir	0.8	5	0.16
Lower Basin river stations	0.6	4	0.15

A major factor in the noted increase is probably due to the higher solubility of uranium as mentioned in Part II. After uranium and radium–226 from uranium mill discharges are assimilated by the Upper Basin sediments, the higher solubility of uranium causes it, and its associated alpha activity, to be leached back to the overlying waters more rapidly than the radium–226 as the sediments are moved downstream. The net result is a proportionate lowering of gross alpha activity in sediments as one proceeds downstream, since the uranium (and its alpha activity) is being released to the overlying waters at the faster rate. Since many other factors affect the uranium concentration in water (primarily liquid wastes from uranium mining and milling operations), it is difficult to substantiate the above theory by examination of uranium concentrations found in Basin waters.

It has been noted that the relatively small number of samples collected in most of the Lower Basin makes it difficult to arrive at statistically reliable figures and relationships. In addition to the number of samples, sampling techniques may also have affected the results. Lake Mead results are averaged from twenty-one different sampling stations while the other reservoirs have been sampled at only one or two locations. Since the reservoir samples are collected from the surface of the bottom deposits, yearly deposition variation and difficulty of returning to the identical sampling point each year may easily affect the results. Nevertheless, the Upper Basin relationships found between radium and gross alpha provide an excellent tool for determining radioactivity conditions in sediments.

A similar and probably more important and useful relationship has been found between radium–226 concentrations in water and sediment collected at the same locations. For background stations, radium–226 in water (pg/liter) averages approximately 4 percent of the radium–226 in sediments (pg/gram). At non-background stations, water concentrations average approximately 13 percent of the sediment concentrations. Except for two figures of 34 and 48 percent at Yuma, Arizona and Bedrock, Colorado, respectively, these figures range from 1.7 to 6.4 percent at background stations and from 8.5 to 22.6 percent at non-background stations. Why these two are so much higher is not evident.

When comparing the levels of radioactivity found in water and sediments in the 1950's as reported in Part I to those reported in Parts II and III, it is evident that there has been a substantial reduction in radioactive contamination of Colorado River Basin streams. The large decreases which can be observed are a result of concerted waste control programs undertaken by the various uranium mills in the Basin since 1960, and demonstrate the great degree of improvement of surface water quality that has been achieved by reasonable and economical pollution abatement practices.

The results also demonstrate the value of a conscientious surveillance program in defining the areas of needed control measures and the subsequent effects and efficiency of these measures. Valuable by-products of the surveillance program have been the knowledge obtained of methods and rates of radioactivity transport and distribution, plus the appearance of definite relationships between radioactive concentrations in the various media discussed in this report.

Analytical Methods

The analytical procedure for radium–226 used in the earlier studies discussed in Part I was a non-emanation technique. Sensitivity

was improved in the latter studies by using an emanation technique and larger sample volumes. Composited samples, analysed by the method in Part I were checked against the emanation technique. Uranium determinations were made by fluorometric techniques. Reference 13 provides details of the uranium and emanation methods as well as precision and accuracy figures. Gross alpha determinations were made by internal proportional counting techniques.

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The cooperation and contributions of the various agencies of the States of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming are also gratefully acknowledged.

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RADIONUCLIDE ANALYSES OF COAST GUARD WATER SUPPLIES, JANUARY–DECEMBER 1963

U.S. Coast Guard and Division of Radiological Health, Public Health Service

The Coast Guard Water Sampling Program was initiated in 1957. From 1957 through 1960, monthly samples of several roof-collected rain water cistern supplies were routinely analyzed for beta activity by the Robert A. Taft Sanitary Engineering Center (*1*). Low radioactivity concentrations after 1960, two years after cessation of nuclear weapons tests in 1958, led to the termination of this sampling program.

Since October 1961, drinking water samples have been obtained from seven Coast Guard Loran Stations in Alaska. One gallon samples of potable tap water are collected from each station. Each water supply is an artificial impoundment or lake. Water from these reservoirs is usually filtered, pumped into a tank or cistern and chlorinated before use. The sampling sites are shown in figure 1.

The gross alpha and beta analyses and the selected specific radionuclide analyses reported in table 1 were performed by Southwestern Radiological Health Laboratory at Las Vegas, Nevada. Radionuclide analyses for strontium–90 were carried out only on samples for which this analysis was specifically requested. All other radionuclide analyses were performed by gamma spectroscopy.

The radionuclide analyses reported in table 1 were performed by the Southwestern Radiological Health Laboratory at Las Vegas, Nevada.

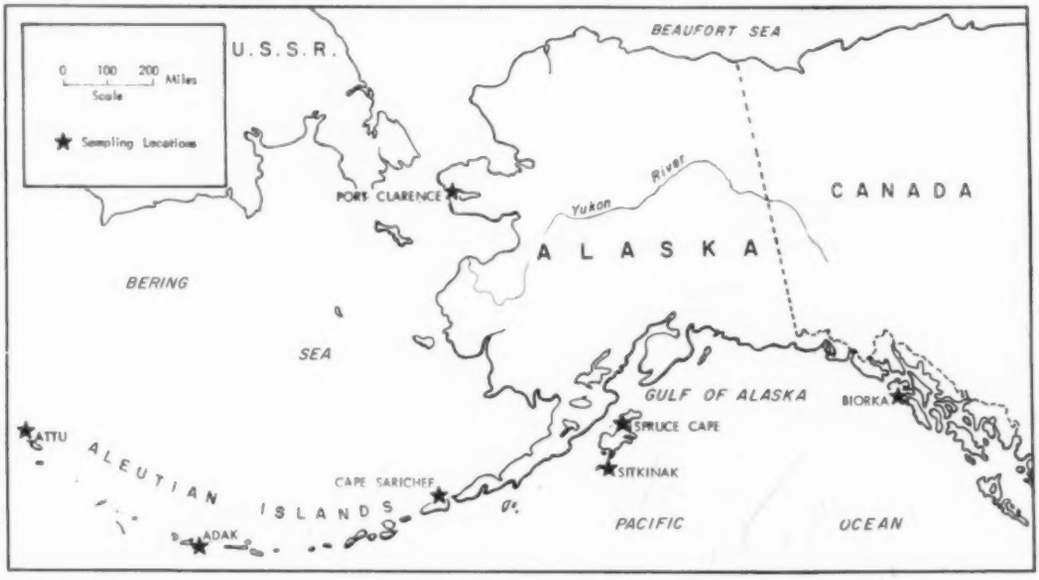

FIGURE 1.—COAST GUARD LORAN STATION WATER SAMPLING LOCATIONS

TABLE 1.—RADIONUCLIDES IN WATER SAMPLES FROM U.S. COAST GUARD LORAN STATIONS, JANUARY 1963–DECEMBER 1963

[Concentrations in pc/liter]

Alaskan location	Collection date 1963	Gross alpha	Gross beta	Sr^{90}	I^{131}	Ba^{140}	Cs^{137}	Ru^{103}–Ru^{106}	Zr–Nb^{95}
Adak	April 23	4.3	348	[a]—	<10	<10	70	175	900
Attu Island	[b]	0.6	49	—	60	<10	<5	—	<10
	February 5	1.4	33	—	<10	<10	<5	—	<10
	May 7	9.9	80	—	<10	<10	<5	—	55
	June 14	1.9	30	—	—	—	—	—	—
	July 16	<0.1	26	—	<10	<10	<5	—	—
	August 7	0.6	20	—	<10	<10	<5	—	<10
	September 5	<0.1	34	—	<10	<10	<5	—	<10
	October 1	3.9	17	—	<10	<10	<5	—	<10
	November 5	1.1	20	—	<10	<10	<5	<10	<10
	December 3	1.5	21	—	<10	<10	<5	<10	<10
Biorka	August 1	<0.1	142	—	<10	<10	<5	—	—
	December 12	<0.1	44	—	<10	<10	<5	<10	<10
Cape Sarichef	January 22	0.7	43	—	<10	30	<5	—	<10
	May 8	<0.1	12	—	<10	<10	<5	—	<10
	June 10	0.3	49	—	<10	<10	<5	—	<10
	July 15	<0.1	6	—	<10	<10	<5	—	—
	August 8	<0.1	6	—	<10	<10	<5	—	—
	September 12	<0.1	9	—	<10	<10	<5	—	<10
	October 17	<0.1	21	—	<10	<10	<5	—	<10
	November 27	7.2	9	—	<10	<10	<5	<10	<10
	December 10	<0.1	4	—	<10	<10	<5	<10	<10
Port Clarence	January 22	3.3	17	—	<10	<10	<5	—	<10
	May 8	<0.1	7	—	<10	<10	<5	—	<10
	June 8	<0.1	126	6.0	<10	<10	<5	—	<10
	July 6	0.8	85	9.0	<10	<10	5	—	40
	August 8	<0.1	82	—	<10	<10	<5	—	—
	September 12	<0.1	18	—	<10	<10	<5	—	<10
	October 12	<0.1	13	—	<10	<10	<5	—	<10
	December 11	<0.1	44	—	<10	<10	<5	<10	<10
Sitkinak Island	January 30	—	64	—	<10	30	<5	—	50
	April 15	<0.1	44	—	<10	<10	<5	—	<10
	May 22	0.8	51	—	<10	<10	<5	—	<10
	June 3	0.8	41	—	<10	<10	<5	—	<10
	June 14	0.8	26	—	<10	<10	<5	—	<10
	July 22	<0.1	24	—	<10	<10	<5	—	—
	August 7	<0.1	17	—	<10	<10	<5	—	—
	September 12	<0.1	17	—	<10	<10	<5	—	<10
	October 10	3.6	16	—	<10	<10	<5	—	<10
	November 13	26.2	17	—	<10	<10	<5	<10	<10
	December 6	1.6	26	—	<10	<10	<5	<10	<10
Spruce Cape	January 22	0.8	144	—	20	<10	<5	—	90
	May 3	1.7	54	—	<10	<10	<5	—	<10
	June 12	0.3	10	—	—	—	—	—	—
	July 8	<0.1	31	—	<10	<10	<5	—	<10
	August 5	<0.1	34	—	<10	<10	<5	—	—
	September 9	<0.1	34	—	<10	<10	<5	—	<10
	October 3	<0.1	34	—	<10	<10	<5	—	<10
	November 5	1.1	30	—	<10	<10	<5	—	—
	November 12	1.1	11	—	<10	<10	<5	<10	<10
	December 9	2.8	38	—	<10	<10	<5	<10	<10

[a] Dash indicates no analysis.
[b] Date of collection unknown (counted on January 7, 1963).

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Previous coverage in *Radiological Health Data:*

Period	Issue
October-November 1959	*June 1960*
October-December 1959	*July 1960*
Fourth quarter 1959, and First and second quarters 1960	*August 1961*
October 1961-April 1962	*October 1962*
May-December 1962	*August 1963*

Section IV—Other Data

ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U. S. Atomic Energy Commission receives from its contractors periodic reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of environmental radioactivity data for 23 AEC installations have appeared periodically in *RHD* since November 1960. Summaries follow for Bettis Atomic Power Laboratory, Mound Laboratory and Shippingport Atomic Power Station.

Releases of radioactive materials from these installations for the periods covered in the reports below are regulated in accordance with AEC standards as set forth in the Federal Register Title 10—Part 20 (*1*). The appropriate concentration standards are given in table 1.

TABLE 1.—MAXIMUM PERMISSIBLE CONCENTRATIONS PERTAINING TO ENVIRONMENTAL MONITORING AT BETTIS ATOMIC POWER LABORATORY, MOUND LABORATORY AND SHIPPINGPORT ATOMIC POWER STATION [a]

Radionuclide	Air (pc/m³)	Water (pc/liter)
Mixture, if Sr^{90}, I^{129}, Pb^{210}, Po^{210}, Ra^{223}, Ra^{226}, Ra^{228}, Pa^{231}, and Th-nat are not present [b]	—	2,000
Mixture, if Sr^{90}, I^{129}, Pb^{210}, Ac^{227}, Ra^{228}, Pa^{230}, Pu^{241}, Bk^{249} are not present [b]	100	—
Hydrogen-3 (tritium)	200,000	3,000,000
Strontium-90	10	100
Xenon-133	300,000	—
Polonium-210	20	700
Uranium natural	2	20,000
Plutonium-239	0.06	5,000
Mixture of unidentified radionuclides	0.04	10

[a] The concentration standards given here were taken from the Atomic Energy Commission's regulation 10 CFR Part 20, Federal Register, (*1*).
[b] "Not present" implies that the concentration of the nuclide is small compared with its appropriate MPC. According to Federal Register, Title 10, Part 20, (*1*), a group of nuclides may be considered not present if the ratio of each nuclide to its appropriate MPC is equal to or less than 1/10 and if the sum of these ratios for the group in question is equal to or less than ¼.

1. BETTIS ATOMIC POWER LABORATORY JULY–DECEMBER 1963[1]

Westinghouse Electric Corporation

The Bettis Atomic Power Laboratory (BAPL), operated for the Atomic Energy Commission by Westinghouse Electric Corporation, was established in 1949 to conduct research and development operations related to naval atomic propulsion systems and the central station atomic power reactor at Shippingport, Pennsylvania.

The data for the 6-month period from July through December 1963 are given in table 2. Figure 1 shows the location of the sampling sites.

[1] Data and information summarized from reports to the Pennsylvania Department of Health entitled *Environmental Radioactivity at the Bettis Atomic Power Laboratory: PNRO-DEV-128.* The reports were prepared by BAPL's Industrial Hygiene Department and transmitted through the AEC Pittsburgh Naval Reactors Office.

Liquid Radioactive Waste

Liquid effluent discharged from the Laboratory is sampled continuously and composite samples are analyzed weekly for gross alpha and gross beta-gamma activity and quarterly for strontium–90 activity. In addition, analysis for total uranium alpha activity is performed whenever the combined gross alpha and beta-gamma activities exceed 2,000 pc/liter.

The average concentration of gross radioactivity, including fallout, in the liquid effluent during the second six months of 1963 was 120 pc/liter. This was not significantly different from the first six month's average concentration of 150 pc/liter. The average concentration of strontium–90 for the second quarter of 1963 was 5.9 pc/liter. The average concentration of strontium–90 for the third quarter of 1963 was 23 pc/liter.

The strontium–90 analyses for the fourth quarter 1963 have not been completed.

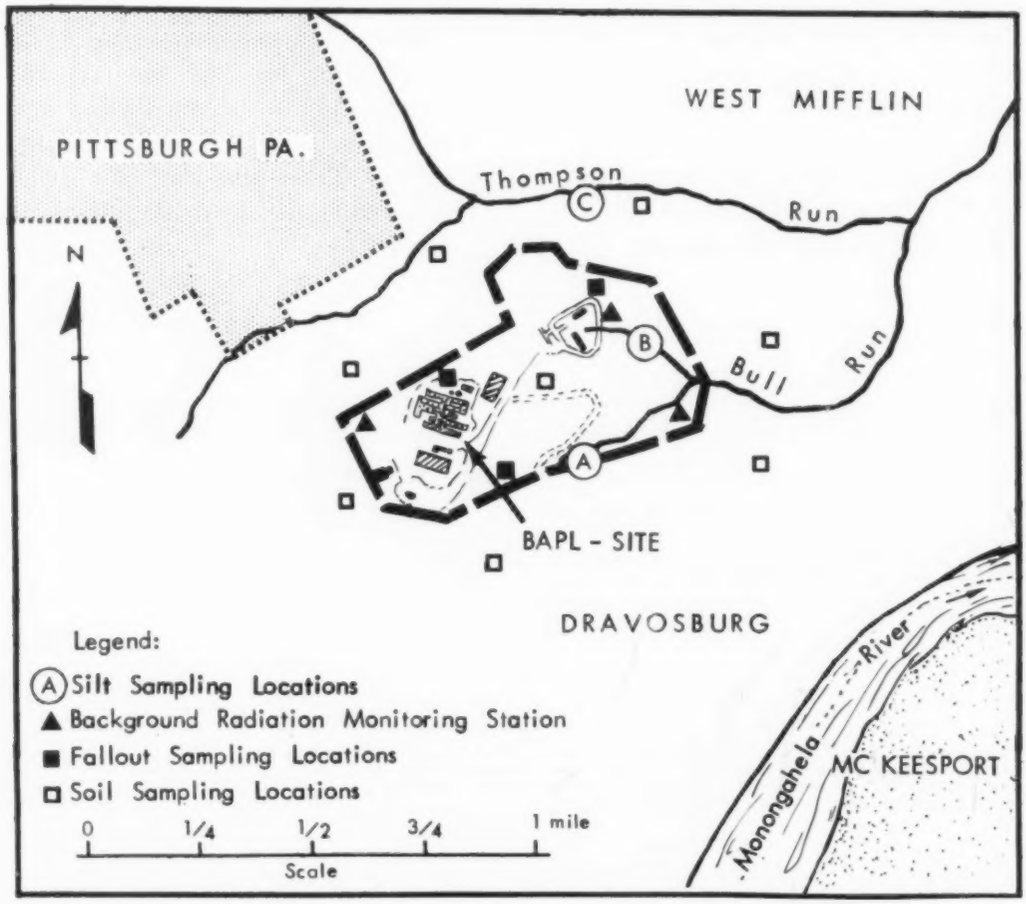

FIGURE 1.—BETTIS ATOMIC POWER LABORATORY SAMPLING STATIONS

TABLE 2.—RADIOACTIVITY IN THE BAPL ENVIRONMENT, SECOND-HALF 1963

Type of measurement		3rd quarter	4th quarter
Liquid wastes (pc/liter)			
Gross activity [a]		152	89
Strontium-90		23	[b]
Beta-gamma dose rate (mrad/hr)			[c].021
Beta activity in fallout (mc/mi²/mo)		92	[d] 15
Stream silt (pc/gram)			
Alpha:	Station A	95	38
	Station B	17	21
	Station C	19	36
Beta:	Station A	85	37
	Station B	19	25
	Station C	16	7.3

[a] An environmental MPC of 2,000 pc/liter is used as the standard for liquid wastes effluent (see table 1).
[b] The fourth quarter strontium-90 has not been determined as of present.
[c] Beta-gamma activity values are semi-annual averages.
[d] Analysis for December not complete.

Background Monitoring Stations

Four background monitoring stations are in continuous operation on the Laboratory property. Three of the stations are located at the perimeter of the Laboratory and one station is centrally located with respect to the main Laboratory area. These stations continually measure and record the external beta-gamma radiation level, the external gamma radiation level and the beta-gamma activity of particulates in air as collected by a continuous air monitor of the moving filter type. An air sample is continuously collected at two of the stations. The filters removed from the high volume air samplers are retained for specific analysis when required to identify the nature of the airborne activity. External gamma activity for the three perimeter stations are given in table 2.

Background beta-gamma radiation intensities averaged 0.02 mr/hr during this period. This is not significantly different from the background radiation intensities measured during the first six months of 1963.

Soil samples

Soil samples are collected at eight locations on and off site and are retained for a period of two years. These samples are analyzed for radioactivity only on an "as required" basis. No analyses were required during the 6-month period ending December 1963.

Stream Silt

Stream silt samples are collected quarterly at three locations described as follows:

Location A: Bull Run downstream from the point where the water leaves the main laboratory area at the first point where silt has accumulated.

Location B: C-Area effluent downstream from its origin at the first point where silt has accumulated.

Location C: Thompson Run downstream from the junction of the High Temperature Test Facility effluent and Thompson Run at the first point where silt has accumulated.

These samples are analyzed quarterly for gross alpha activity and gross beta-gamma activity. Table 2 shows that samples from location A tend to have slightly higher activity than samples from location B and C.

Fallout

Fallout samples, collected at three locations at the perimeter of the Laboratory over a period of one month in high-wall stainless steel pots, are analyzed for gross alpha activity and gross beta-gamma activity.

The average concentration of radioactive fallout for five months during the last half of 1963 was 61 mc/mi²/mo. There was a decrease in fallout activity during this period as compared to the first six months of 1963.

Recent coverage in *RHD:*

Period	Issue
January to June 1961	*April 1962*
July 1961 to June 1962	*April 1963*
July 1962 to June 1963	*April 1964*

2. MOUND LABORATORY, JULY 1963–DECEMBER 1963

Monsanto Research Corporation

Of the radionuclides in use at Mound Laboratory, only polonium–210, plutonium–239, and hydrogen–3 (tritium) are potential environmental contaminants. No measurable amounts of penetrating radiation such as gamma or hard beta have contributed to the environment contamination by the Laboratory during the period covered by this report.

The environmental monitoring program, conducted by the Monsanto Research Corporation, is planned and coordinated with regard to all of the various projects performed in the Laboratory. Water and air monitoring methods and results are discussed below.

Air Monitoring

A continuous air monitor for measurement of tritium and particulate air sampling equipment for measurement of alpha activity are mounted on a one-ton panel truck for use in the routine monitoring of the environmental air at 95 locations selected within a radius of 20 miles. The choice of sites on a given day depends on the wind direction at the time of collection.

During the 6-month period ending December 1963, 144 samples were taken for determination of tritium in air. In all cases tritium was nondetectable.

Monitoring for possible polonium–210 and plutonium–239 released to the environment is accomplished by determination of long-lived gross alpha activity on filter paper samples. Counting is done in a low-background proportional counter. Sufficient delay time is allowed after collection to minimize interference from the daughter products of radon and thoron. The measured concentrations of alpha activity in air are summarized in table 3. No specific determinations of polonium–210 or plutonium–239 were made, since the alpha activity remained substantially below the environmental MPC's for these nuclides (see table 1). It may be observed that the largest difference between upwind and downwind average alpha activity was 0.0028 pc/m^3 for second half 1963. The gross alpha air concentration averaged over the 6-month period was 9.5 percent of the environmental MPC for plutonium.

Water Monitoring

Liquid radioactive waste materials from polonium operations at the Laboratory are processed in a special waste disposal plant designed to reduce radioactivity to a concentration level at which it may be discharged to the Great Miami River (station 2, figure 2). Liquid waste from these activities is small in volume, is handled separately as a packaged waste and is not discharged to the river. Helium–3, which is purified at the Mound Laboratory, yields small quantities of tritium. Liquid wastes from this work, also small in volume, are treated separately (diluted with water when necessary) to assure that the radioactivity content is below the maximum permissible concentration for discharge to the Great Miami River.

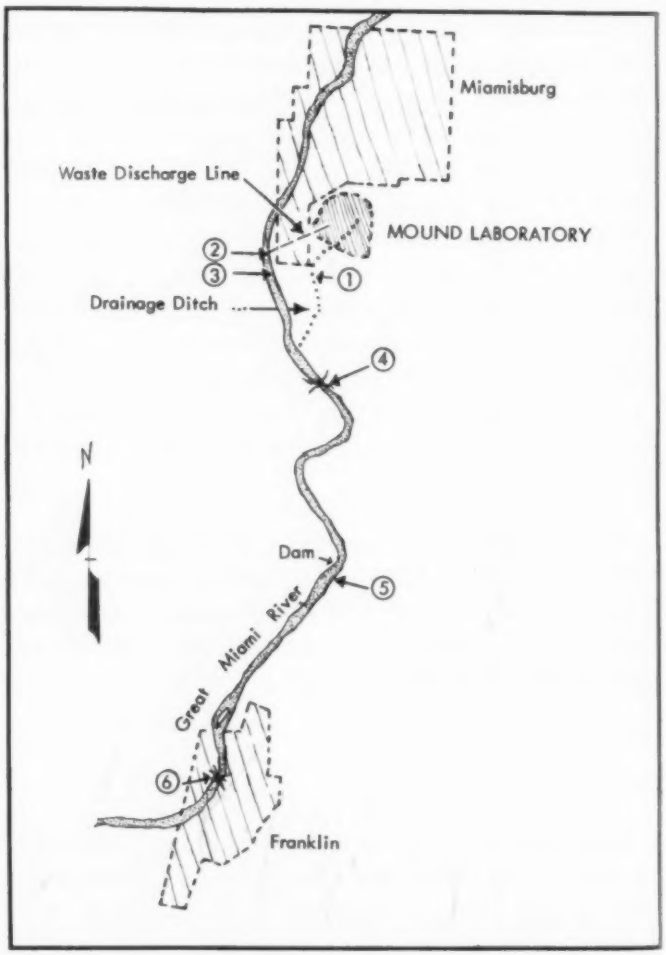

FIGURE 2.—WATER SAMPLING LOCATIONS IN GREAT MIAMI RIVER, MOUND LABORATORY

TABLE 3.—LONG-LIVED ALPHA CONCENTRATIONS IN AIR IN THE MOUND LABORATORY ENVIRONMENT

[Average concentration in pc/m³]

Direction from laboratory relative to wind	Second half 1963	
	No. of samples	Alpha
Upwind	41	0.0027
Downwind	250	0.0055

Weekly water samples are collected from a drainage ditch and five locations along the Great Miami River as shown in figure 2. The drainage ditch carries away all storm sewer water and liquid tritium wastes from the plant site. Sampling location number 2 is located at the point of discharge of the laboratory effluent to the Great Miami River, and number 6 is five miles downstream from the effluent outlet.

All of the river samples are analyzed for polonium–210. The drainage ditch samples and some of the river samples are analyzed for tritium. Average concentrations of tritium and polonium–210 are given in table 4. The highest polonium–210 concentration during the 6-month period was 120 pc/liter in a sample of Laboratory effluent (station 2) collected during the second half of 1963. This represents 16 percent of the MPC for polonium–210 (see table 1). The highest tritium value found in a sample was equal to the MPC, but the average was 4 percent of the MPC.

TABLE 4.—OFF SITE WATER MONITORING FOR POLONIUM-210 AND TRITIUM FROM MOUND LABORATORY [a]

[Average concentration in pc/liter]

Nuclide and station number (see figure 2)	Second half 1963	
	Number of samples	Concentration
Polonium-210		
2 (effluent)	17	11.2
3	17	2.2
4	17	2.7
5	17	2.2
6	17	2.7
Hydrogen-3 (tritium)		
1 (drainage ditch)	17	500,000
2 (effluent)	17	50,000
4	17	50,000

[a] See table 1 for applicable environmental MPC values.

Recent coverage in *RHD:*

Period	Issue
January-June 1961	*January 1962*
July-December 1961	*June 1962*
January-June 1962	*March 1963*
July 1962-June 1963	*April 1964*

3. SHIPPINGPORT ATOMIC POWER STATION JULY 1963–DECEMBER 1963

Duquesne Light Company, Shippingport, Pennsylvania

Environmental radiation monitoring at the Shippingport Atomic Power Station began with a two-year preoperational survey program to establish background levels.

Following initial operation of the plant in December 1957, this program was continued as originally conceived through the third quarter of 1961, when it was determined that fewer sampling locations closer to the plant would provide equal or better evaluation of the effects of plant operation on the environment.

Release of Radioactive Materials to the Atmosphere

Controlled releases of xenon–133 were made periodically at a concentration of 140,000 pc/m³ at the stack. A total of 351 mc of xenon–133 were discharged during the second half of 1963.

The exhaust from an incinerator for burning contaminated combustible material is passed through a wet scrubber and a high efficiency filter before entering the stack. The average gross radioactivity of incinerator effluent during operation ranged from 5 pc/m³ to 42 pc/m³ during the second half of 1963.

Air Monitoring

Airborne particulates are sampled at three area monitoring stations by means of a continuously moving paper tape sampler with an end-window Geiger-Mueller detector and recorder. Since only one-half hour decay time is

allowed before counting, hence, naturally-occurring radon and thoron daughters are present. Six-month average activities shown in table 5 are for Area monitoring stations 1, 2, and 3, located 150 yards southeast, 150 yards west and one-half mile north-northwest of the stack, respectively.

TABLE 5.—GROSS BETA IN AIR

[Average concentrations in pc/m³]

Station number	Second half 1963
1	2.2
2	2.6
3	2.4

Fallout Sampling

Monthly pot samples were collected at each of the three area monitoring stations (same locations as for air). Gross beta average monthly deposition rates are given in table 6.

TABLE 6.—GROSS BETA IN FALLOUT

[Average monthly deposition in nc/m²]

Station number	Second half 1963
1	113
2	132
3	144

Liquid Radioactive Waste Disposal

Continuous controlled discharges of tritium and unidentified radioactive wastes are made into the Ohio River. The quantities of discharge and average effluent concentration are given in table 7.

TABLE 7.—LIQUID WASTES DISCHARGED INTO THE OHIO RIVER

	Tritium	Unidentified radioactivity
	Second half 1963	Second half 1963
Total discharge (mc)	785	88.7
Average of monthly average concentrations of effluent (pc/liter)	53	2.5

Ohio River Water Monitoring

River water samples were collected by a continuous sampler upstream at the Shippingport condenser cooling water intake and by grab sampling downstream at the condenser cooling water outfall. (The downstream continuous sampler was not functioning.) These samples were analyzed weekly for both alpha and beta, suspended and dissolved radioactivity. The six-month averages of these measurements are given in table 8.

TABLE 8.—RADIOACTIVITY IN OHIO RIVER WATER SECOND HALF 1963

[Average concentrations in pc/liter]

Type of radioactive material	Upstream samples			Downstream samples		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Alpha:						
Suspended solids	0.47	0.08	0.26	0.35	0.09	0.18
Dissolved solids	3.49	0.00	1.15	2.87	0.07	0.16
Total solids	3.96	0.08	1.41	3.22	0.16	0.34
Beta:						
Suspended solids	25.5	2.99	8.76	20.5	3.31	7.75
Dissolved solids	129.4	16.9	53.6	110.2	21.5	47.6
Total solids	154.9	19.9	62.4	130.7	24.8	55.4

REFERENCE

(1) U.S. Atomic Energy Commission: *Rules and Regulations, Standards for Protection Against Radiation*, Title 10 CFR 20, Government Printing Office, Washington, D. C.

Previous coverage in *RHD:*

Period	Issue
1959	*July 1960*
First quarter 1960	*December 1960*
Second quarter 1960	*January 1961*
Third and fourth quarters 1960	*October 1961*
First and second quarters 1961	*April 1962*
Second half 1961 and first half 1962	*May 1963*
July 1962-June 1963	*March 1964*

REPORTED NUCLEAR DETONATIONS, OCTOBER 1964

During October 1964, four United States nuclear tests were announced by the Atomic Energy Commission and one nuclear test was announced by Communist China.

The first of the U. S. tests was of low intermediate yield (20–200 kilotons), and was conducted underground on October 2, at the Nevada Test Site. Low-yield tests (less than 20 kilotons) were conducted underground at the Site on October 16 and October 31, respectively. The fourth U. S. test was a deep underground nuclear explosion (equivalent to about 5000 tons of TNT) on October 22 in the Tatum Salt Dome near Hattiesburg, Mississippi. This event, nicknamed *Salmon,* was the first of 3 planned in the series designated as Project Dribble, which in turn is a part of the Vela Uniform Program sponsored by the Advanced Research Projects Agency of the Department of Defense. Vela Uniform is the nation's seismic research program designed to improve our capability to detect, identify and locate underground nuclear detonations.

The detonation of the Chinese Communist device took place on October 16 and preliminary analysis of airborne radioactive debris indicates it involved a low-yield fission device employing uranium–235.

Arbitrary *RHD* reference numbers applied to the four U. S. tests are 167 through 170 in chronological order; the Chinese test is given the identifying designation C–1.

The Public Health Service reported that small amounts of iodine–131 had been detected in some Pasteurized Milk Network milk samples during the last week of October.

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UNITS AND EQUIVALENTS

Symbol	Unit	Equivalent
Bev	billion electron volt	
cpm	count per minute	
dpm	disintegration per minute	
g	gram	
kg	kilogram	1 kg = 1000 gm = 2.2 pounds
km^2	square kilometer	
kvp	kilovolt peak	
m^3	cubic meter	1 m^3 = 1000 liters
ma	milliampere	
mas	milliampere-second	
Mev	million electron volts	
mi^2	square mile	
ml	milliliter	
mm	millimeter	
mrad	millirad	
mrem	millirem	
mr/hr	milliroentgen per hour	
mμc	millimicrocurie	1 mμc = 1 nc
nc	nanocurie	1 nc = 1000 pc = 1 mμc =10^{-9} curies
nc/m^2	nanocurie per square meter	1 nc/m^2 = 1 $m\mu c/m^2$ = 1,000 $\mu\mu c/m^2$ = 1 mc/km^2 = 2.59 mc/mi^2
pc	picocurie	1 pc = 1 μμc = 10^{-12} curies
r	roentgen	
μμc	micromicrocurie	1 μμc = 2.22 dpm

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

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10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
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